

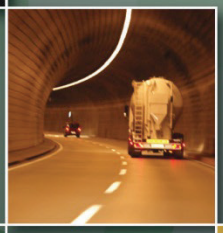



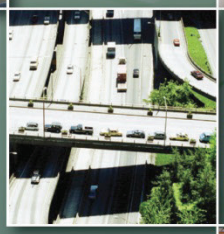

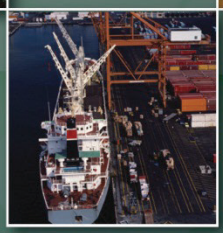

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO
The Voice of Transportation

AASHTO Transportation Asset Management Guide

A FOCUS ON IMPLEMENTATION

EXECUTIVE SUMMARY

June 2013

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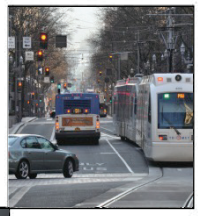

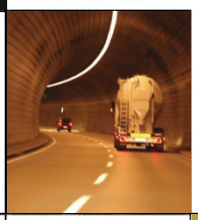



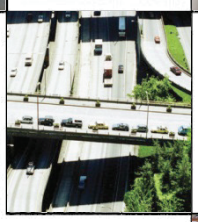
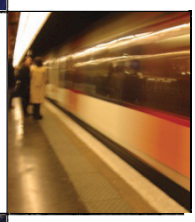
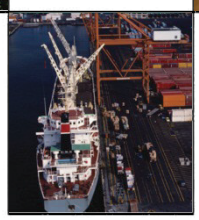

AASHTO Transportation Asset Management Guide

A FOCUS ON IMPLEMENTATION

EXECUTIVE SUMMARY

June 2013

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Acknowledgements

The Executive Summary of the *AASHTO Transportation Asset Management Guide—A Focus on Implementation* was developed in partnership between the Federal Highway Administration (FHWA) and AASHTO. The FHWA Transportation Asset Management Expert Task Group oversaw the preparation of the content of the Executive Summary.

A. Transportation Asset Management Guide—A Focus on Implementation

Infrastructure supports the nation's economy and lifestyle, enabling mobility while providing an acceptable level of speed, safety, security, comfort, and reliability. Transportation agencies in the United States have a long history of building roads, bridges, transit systems, and other infrastructure and managing an expanding asset base. However, over the past decade there has been a growing awareness that current methods of transportation infrastructure management are inadequate to meet the demands of American citizens and industry. With the published reports of two presidential and congressional commissions (U.S. General Accounting Office), it is clear that the general public and elected federal, state, and local officials will be demanding from transportation agencies and providers:

- greater accountability in the effective use of federal funds,
- an increased relationship between performance and funding, and
- more sustainable transportation solutions.

Transportation Asset Management (TAM) is therefore needed to meet the new demands of a rapidly changing transportation business environment. Traditional management methods will no longer be sufficient to meet 21st century business and political demands. Implementing TAM represents good public policy and service [Section 1.1.1].

There is no "one-size-fits-all" TAM solution for an agency. There are many reasons why the appropriate level of asset management practice varies among organizations, or within an organization, as TAM practices consolidate. These reasons may include:

- Agencies vary in their level of asset management maturity, knowledge, experience, political and physical environment, and resources.
- Some aspects of TAM, such as consultation with customers over levels of service, may be totally new to the agency.
- Agencies may wish to integrate other aspects, such as demand forecasting, risk management, asset criticality, asset valuation, and cost optimization.
- The characteristics of different transport networks vary considerably. For example, the needs of a sparsely populated county may differ significantly from those of a major metropolitan area or of an interstate system [Section 1.1.2].

Executive Summary

This *AASHTO Transportation Asset Management Executive Summary* serves as a companion to the *AASHTO Transportation Asset Management Guide—A Focus on Implementation,* which takes as a starting point the *Transportation Asset Management Guide* published by AASHTO in November 2002. The *AASHTO Transportation Asset Management Guide—A Focus on Implementation* is focused on implementing TAM. All three documents should be read and used together—they are complementary.

The *AASHTO Transportation Asset Management Guide* provides considerable background information about Transportation Asset Management, the advantages of using TAM, and an approach that agencies can use to identify where they are now and where they should focus their asset management efforts.

The *AASHTO Transportation Asset Management Guide—A Focus on Implementation* is presented in three key parts:

- Part 1, which is focused on organizing and leading TAM. Part 1 is of most interest to executive management.
- Part 2, which is focused on processes, tools, systems, and data. Part 2 is of most interest to practitioners,
- Appendices, which include examples of asset management plans and four in-depth case studies of local and international agencies' experiences in implementing TAM.

The guide is a "step-by-step" presentation of the tasks to implement asset management in a transportation agency [Section 1.2.1]. It is structured so that a reader can use a particular section or topic as a source of advice (typically a practitioner) or use the whole in order to drive a systematic agency-wide implementation (typically the executive) [Section 1.2.2].

Chapters 1 through 4 provide the context and preparatory steps that any agency will need to undertake as it prepares for asset management implementation. The material in these chapters is broadly applicable to agencies at any level of maturity. In Chapter 4, differences emerge among agencies at varying levels of maturity, as the more advanced agencies will typically have more formalized and extensive TAMPs in place. Chapters 5 to 8 are designed to be used selectively, depending on the priority areas of
improvement identified by the gap analysis in Chapter 2. These later chapters are focused on the specific tools, methods, and information technology resources required in order to reach the more mature stages. The most mature agencies use all the tools described here. However, it is important not to be overwhelmed by their breadth and depth. Agencies climbing the maturity scale which might not use many of these tools today can set their own priorities for near-term implementation activities. Figure 1 illustrates the guide structure through the TAM implementation steps [Section 1.3].

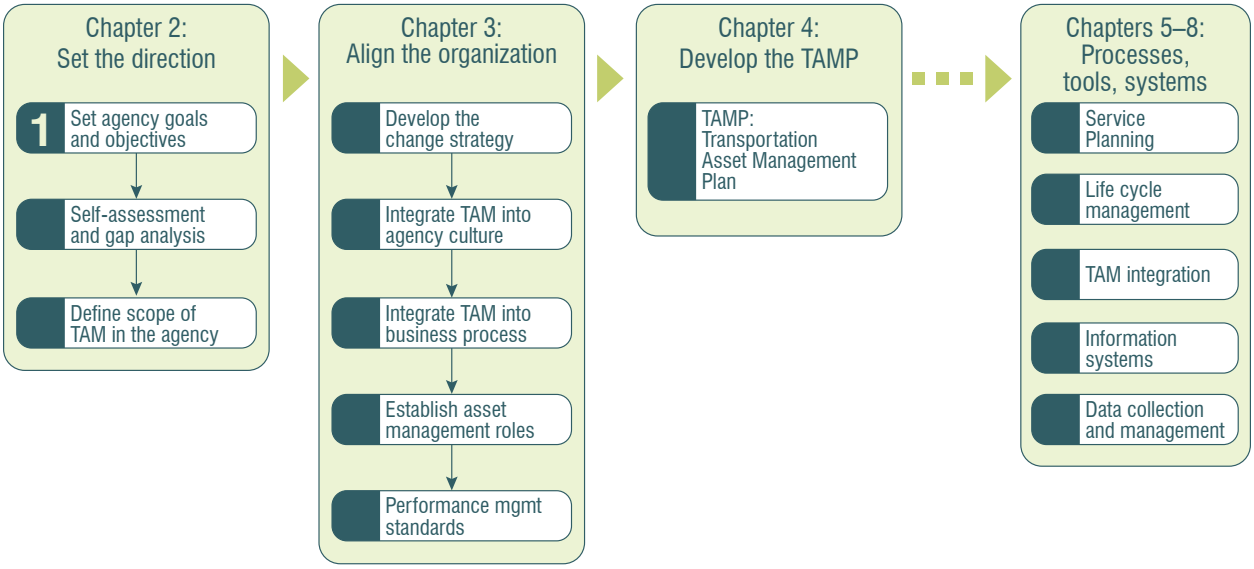

Figure 1. TAM Implementation Steps

"Transportation Asset Management 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."

NCHRP Report 632 (National Cooperative Highway Research Program, 2009)

The Total TAM Process

TAM needs to be embedded in the business planning processes of an agency, from strategic through tactical to operational planning. TAM includes the development of asset management policy, an organizational statement that can establish the framework for securing alignment and providing direction for asset management planning. It extends through producing and using the Transportation Asset Management Plan (TAMP) to daily operation of facilities and reporting on the achievement of programs and outcomes [Section 1.4.1].

TAM yields many important benefits to the agency, including:

- Long-term view.
- Clear relationships, transparency, and accountability.
- Provides the desired levels of service.
- Plans for growth.
- Maximizes the benefits of infrastructure.
- Better use of existing funds. [Section 1.4.2]
- Improves agency competitiveness for limited funds.
- Helps build constructive political relationships. [Section 1.4.3]

There are three key principles that underpin TAM:

- Recognizing the economic value of assets.
- Achieving economic efficiency and the optimization of expenditure over the asset's life cycle.
- Understanding the role of the agency as "steward" of the assets. [Section 1.4.4]

There are many features that characterize TAM effectiveness in an agency, such as:

- Takes a network view.
- Aligns with strategic directions.
- Aligns leadership within the agency.
- Communicates with stakeholders.
- Makes data-driven, informed decisions.
- Integrates agency programs and budgets.
- Monitors outcomes.
- Focuses on continuous improvement. [Section 1.4.5]

B. Setting the Direction for Asset Management

Step 1. Set Agency Goals and Objectives for TAM

The starting point for any agency is having a clearly defined mission and organization-wide strategic goals and objectives. Quantitative, proactive decision making is a powerful tool to improve the agency's ability to achieve its mission under a variety of policy scenarios.

High-level goals may also be referred to as vision or outcomes, and they provide the agency with a sense of purpose, direction, and a high-level picture of what it wishes to achieve as an organization. This should be clearly understood by management, staff, and external stakeholders. Many organizations also prepare a strategic plan, with high-level indicators or performance measures to provide information on what is being achieved.

Setting goals and objectives for TAM or a vision of what TAM means to the agency, and growing internal commitment to achieving the vision, is an essential leadership role. The agency's goals and objectives need to give a clear signal that asset management is a means to help it accomplish its mission more efficiently and effectively with limited funds. [Section 2.1]

Various approaches are described below that can assist the executive in establishing clear goals and objectives to be cascaded to the practitioner level, such as:

- **Review enterprise strategy—ensure that the agency has a well-defined mission and goals.** A key component of successful asset management is the establishment of TAM goals and objectives, which are quantified by performance measures. Measures need to have targets with a set timeframe and available resources. [Section 2.1.1]
- **Define the context for setting TAM objectives—identify the factors that drive the objectives.** In its generic sense, the purpose of TAM is "to meet a required level of service, in the most cost effective manner, through the management of assets for present and future customers." To do this, TAM focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based on quality information and well-defined objectives. The objectives and service levels are quantitative and are related directly to the agency mission. [Section 2.1.2]
- **Determine the preferred enterprise management framework—how the agency will manage organizational performance.** Once enterprise objectives are understood, asset management policy, strategy, and goals should be specified to support the agency's overall objectives. An agency can consider multiple frameworks for applying performance measurement to management processes, including those provided by Baldrige, Six Sigma, the Balanced Scorecard, and Publicly Available Specification PAS55. [Section 2.1.3]
- **Link TAM to organizational planning, strategy, and policy—integrate TAM with the agency's business processes.** TAM interacts with every aspect of an agency's business, from strategy development, through planning and policy making to the individual member of the work crew fixing a pothole on a local road. All of these business processes share a common understanding of levels of service, both current and future, the quantitative performance objectives of the agency. A set of universally-understood performance expectations for the agency as a whole permeates all business processes that carry out the agency's mission, as depicted in Figure 2. [Section 2.1.4]

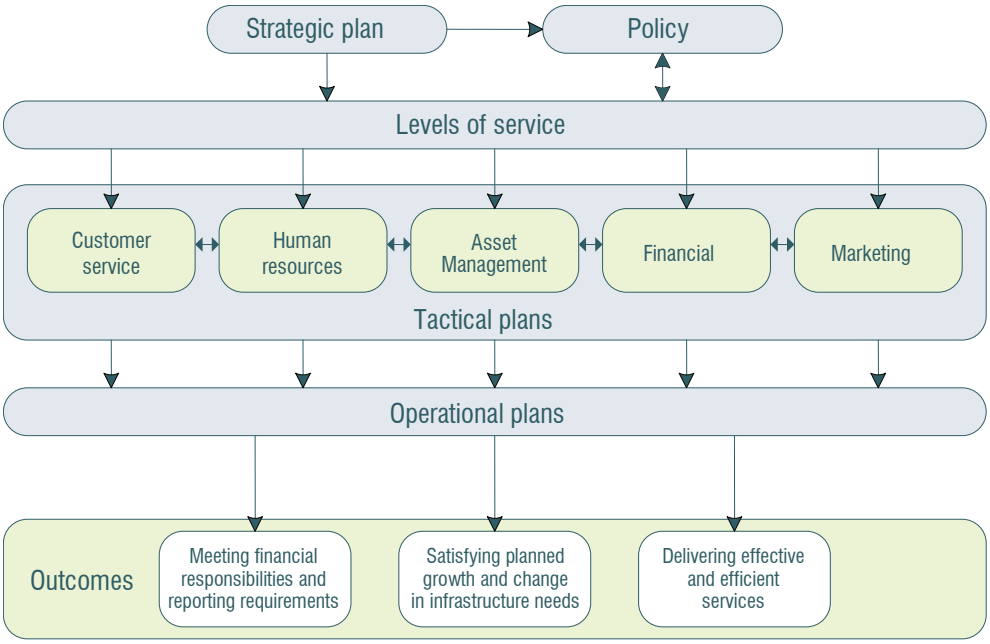

Figure 2. Integrate Levels of Service with Decision Making

- **Obtain organizational commitment—ensure buy-in.** Critical to ensuring actual implementation of TAM and its integration into the agency is the process of obtaining organizational commitment. The following steps can be applied to ensure buy-in throughout the agency, particularly in the early stages of TAM implementation:
  - Raise awareness within the agency management team of benefits of asset management, including related policy and financial implications.
  - Involve key players.
  - Include practical, concrete examples with tangible, short-term goals that can be measured when communicating asset management objectives to staff.
  - Ensure proper resources and training are made available.
  - Establish a continual review process and keep staff fully informed of targets and progress. [Section 2.1.5]

Step 2: Perform an Agency Self Assessment and TAM Gap Analysis

The next step is to assess the current status or maturity level of TAM and determine the actions that need to be taken to achieve TAM improvements. The four key parts of this assessment include: [Section 2.2]

- **Strategic self assessment—using the tool that is described in the *AASHTO Transportation Asset Management Guide* to obtain a high-level picture of where the agency is at present.** The Self Assessment Tool in the *AASHTO Transportation Asset Management Guide* allows an agency to benchmark characteristics for establishing its level of strategic support for sound asset management within the organization. It provides agencies with a structured series of questions that they can ask of themselves. This provides a useful approach in helping to organize thinking and to develop a consensus among top-level managers as to where the agency's strengths and needs for improvement lie, and to then structure an agenda for improvements and change. An agency's responses to the self assessment will guide the actions that need to be undertaken in developing TAM. [Section 2.2.1]
- **TAM maturity model—a concept used to specify the relative position of the agency for each TAM process.** A Maturity Scale is used in this guide to describe levels of TAM achievement in a way that allows

an agency to reliably locate its current position and to help it determine the next steps it should take. Table 1 describes a generalized five- level maturity scale, which can be used in understanding the agency's position on a wide range of TAM practices and is used throughout this guide. It is not intended to replace the *AASHTO Transportation Asset Management Guide* self-assessment methodology, but rather to be used in the next stage of tactical and operational improvement of TAM practices. The following section describes a TAM Gap Analysis Tool, how the TAM maturity scale applies to it, and how the reader can then use the more detailed topic areas within Section E of this Executive Summary to focus efforts on particular weaknesses that may be identified. [Section 2.2.2]

- **TAM gap analysis—a tool for drilling down into the detail of TAM processes which uses the maturity model as its scale.** While the self-assessment process has a valuable framework and identifies a range of useful processes, tools, and approaches for an agency to pursue, it does not provide a step-by-step method of moving from a general action plan to hands-on implementation. That is addressed by the TAM Gap Analysis process. The gap analysis helps to pinpoint the most important areas of deviation between the current and desired states, which form the basis of a list of tasks to be accomplished in order to achieve the desired advancement in maturity. The purpose of the gap analysis is to determine the areas of TAM that require improvement and to allow these to be prioritized. The TAM self-assessment tool and gap analysis tool are illustrated in Figure 3. Once the target levels of maturity have been established, practices in each area are reviewed by considering the questions listed in the tool at the element level. The answer to each question is scored against its level of TAM maturity on a 1 to 10 scale, and any required improvements or shortcomings of the current performance or procedure are noted. The next steps are to determine what needs to be done to close the gap between each individual performance level and its target and to prioritize its closure based on risk and the gaps' relevance to achieving agency performance objectives. Then, analyze and present an improvement plan that addresses the worst of these first.
  The output of this part of the process should be a prioritized list of TAM practice improvements that includes a time for each improvement to be completed, responsibility for carrying out the improvement, and the resources required to do it. The resources include people, time, and money. If there are insufficient resources available, there are two principal options that should be investigated: allocation of more resources and adjustment of the target or extension of the time permitted to reach it. [Section 2.2.3]
- **Identify appropriate TAM practice—suggestions to consider when deciding what TAM practices to focus on.** Determining the set of practices that the TAM program embraces is important in the degree of success the agency is able to achieve. Appropriate practice takes into account an agency's strategic goals and regulatory requirements, customer expectations, nature of the asset, exposure to risk, availability of resources, and benefit-cost analysis. An agency should weigh these factors in determining the practices to be supported by the TAM program. [Section 2.2.4]

Table 1. TAM Maturity Scale

TAM Maturity Scale Level	Generalized Description
Initial	No effective support from strategy, processes, or tools. There can be lack of motivation to improve.
Awakening	Recognition of a need and basic data collection. There is often reliance on heroic effort of individuals.
Structured	Shared understanding, motivation, and coordination. Development of processes and tools.
Proficient	Expectations and accountability drawn from asset management strategy, processes, and tools.
Best Practice	Asset management strategies, processes, and tools are routinely evaluated and improved.

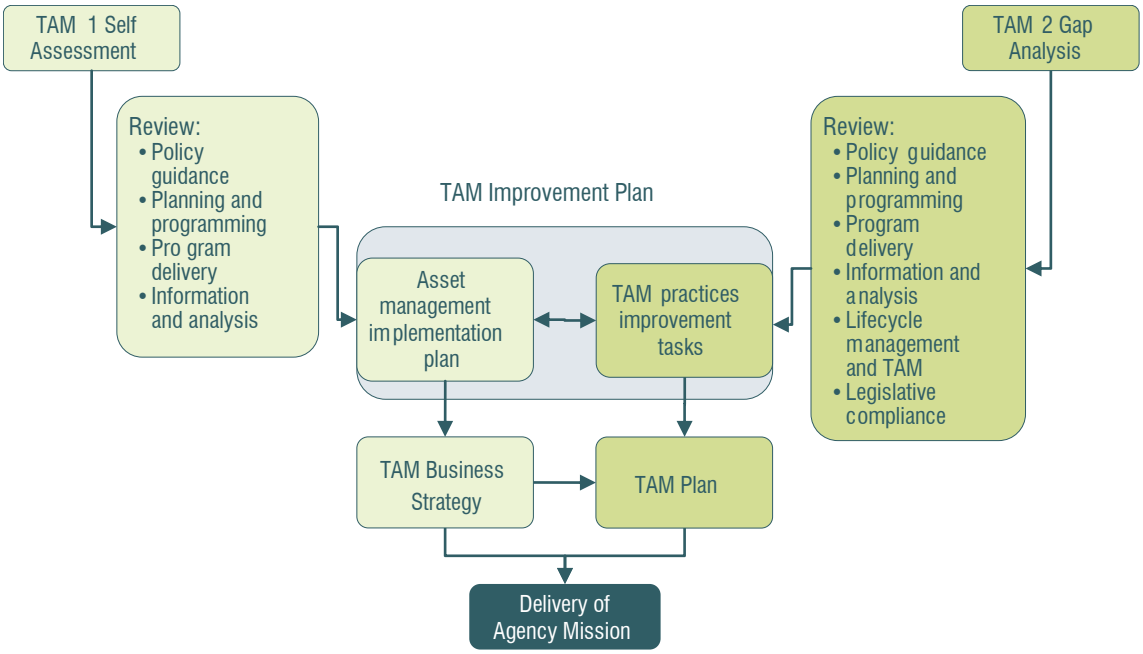

Figure 3. TAM Self Assessment and Gap Analysis

Step 3: Define the Scope of TAM in the Agency

Depending on the management styles of asset management champions in the agency, it is often useful to consider the implementation of asset management as a change process project and manage it using the techniques of project management. Defining the scope of the effort comes first. The following questions are vital to consider when defining the scope:

- Which assets?
- Which actions or decisions?
- Which business processes, including methods and forms of delivery?
- What asset management capabilities?
- What data?

Finding the answers to these questions is part of the implementation process and can be assisted by the self-assessment and gap analysis process. [Section 2.3]

Asset Types

The scope of TAM should include the needs of all assets managed by the agency in delivering services to users and customers. Each of the asset groups will have differing service issues, component lives, risk profiles, and life-cycle management needs. Agencies will very commonly start with just a few asset classes and then build incrementally as their maturity level grows. [Section 2.3.1]

TAM Decision Making

TAM decision making needs to be seen in the context of the agency's mission and the services that it delivers to its customers and road users. Infrastructure assets are employed for a purpose, but it is of equal importance that the assets are managed in an economically efficient manner and in a way which makes best use of available funds. [Section 2.3.2]

C. Aligning the Organization

Step 4: Develop the Change Strategy

Step 4 picks up on the outcomes of the previous step's evaluation of an agency's TAM practices. Depending on the extent of the changes required (e.g., to business processes, roles, or activities), an agency may need to develop a comprehensive change strategy. This should clearly identify what needs to be done and how the agency's executives will involve and motivate staff in achieving the benefits of change. [Section 3.1]

Successful organizational change requires the following activities:

- Convince people of the need for and benefit of change.
- Create a change leadership coalition.
- Develop a vision of changes and strategy.
- Communicate that vision regularly.
- Make actions consistent with the vision.
- Make sure people are involved and empowered to make changes consistent with the vision.
- Reinforce the change effort with short-term successes.
- Keep the focus on the change effort.
- Anchor new approaches into the culture. [Section 3.1.2]

Agencies committed to positive change do not rely on crises as a rationale for change. Rather, they challenge the day-to-day process of the organization through a systematic analysis of what is working well, what needs improvement, and how these areas relate to the agency's mission and goals.

This analysis relies on a willingness to investigate all aspects of "business as usual" with an open mind to determine if new processes, competencies, people, systems, behavior, attitude, communications, and leadership practices are required. The process should be creative, objective, and thorough, involving feedback from all business units and inviting participation from all levels of staff so that information includes the viewpoint of individuals interacting with systems, processes, and customers as well as those with a more strategic overview. Additionally, it should encompass a review of best practices in peer agencies. [Section 3.1.3]

An effective plan for change management must provide guidance on how changes are incorporated and integrated into daily practices, how they are sustained for the long term, and how present changes provide lessons for developing and implementing lasting change at all levels and in all processes of the agency. [Section 3.1.4]

Step 5: Integrate TAM into the Organizational Culture

Continual, honest communication is required for successful collaboration and to build enthusiasm for change. Important considerations when communicating change include:

- The message must be created clearly and with sufficient detail and must convey integrity and commitment.
- The message recipient must be willing to listen, ask questions, and trust the sender.
- The message must be delivered in a format that is accessible and acceptable for both sender and recipient.
- The message content has to be relevant to the recipient and must connect with the recipient's emotions or beliefs in order to have lasting value. [Section 3.2.1]

Speaking positively about the possibilities inherent in change, demonstrating that everyone's opinion is welcome, and providing early, tangible evidence of the value of change are equal to regular communication in their value to gaining commitment to change. [Section 3.2.2]

Agencies need to develop performance-tracking systems that measure the impact of employee efforts on agency performance. These results should be made transparent to everyone so that there is no secrecy about progress toward objectives. Performance measures can even be incorporated into individual employee annual performance reviews. Clear accountability is important, but failing to achieve performance targets should be handled in a way that motivates, as opposed to assigning guilt or blame. [Section 3.2.3]

Step 6: Integrate TAM into Business Processes

TAM implementation typically involves the establishment of linkages and data flows that may not have existed before to existing and new business processes and providing information to support performance measurement across strategic, tactical, and operational levels. [Section 3.3]

Step 7: Establish Asset Management Roles

Asset management is a team effort, requiring a variety of specialized skills and capabilities. In the early stages of implementation, an agency in the Awakening stage might rely on
just one person, or a few scattered people, who have multi-disciplinary training and experience. Once asset management becomes the coordinated effort of multiple individuals, the agency has satisfied a major criterion in moving from the Awakening stage to the Structured stage of asset management maturity.

Establishing new roles and managing the transition from the small "nurturing group" to a formal, mature asset management team is an important leadership task. It requires consideration of individual, team, and organization expectations and how dynamics will change as the formal TAM team is established and developed. [Section 3.4] Figure 4 shows an example of a successful leadership structure for asset management. Every asset management implementation effort needs a project manager, the leader of the effort, who devotes a significant part of his/her time to the project. [Section 3.4.2] Implementation of asset management is most easily launched by the chief executive officer of an agency or by a senior manager with the CEO's blessing. As previously discussed, team-building skills are perhaps one of the most important attribute of this individual, as is motivation and persistence in overcoming the inevitable barriers that appear whenever organizational change is attempted. The Asset Management Leader may come from an engineering, economics, or planning background, preferably a combination of more than one of these.

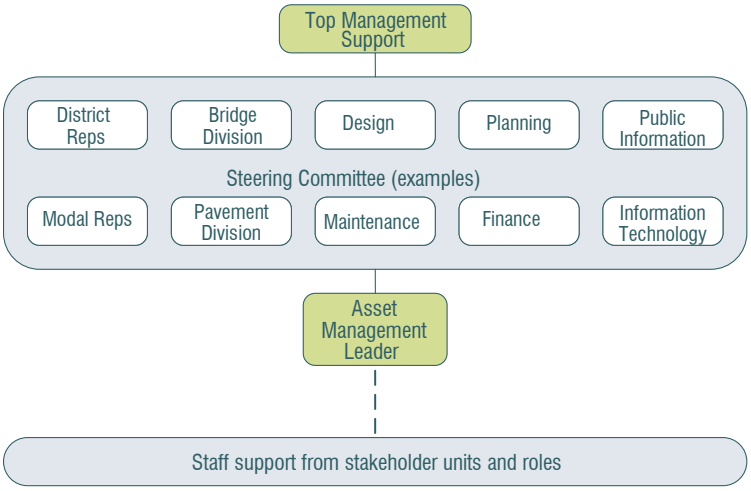

Figure 4. Example Leadership Structure

A Steering Committee of relatively senior managers, overseeing the work of the Asset Management Leader, is also essential. [Section 3.4.2] A major function of the steering committee is to ensure that all parts of the asset management process are functioning together as a unit. [Section 3.4.5.1]
Adequate resources are vital to a successful implementation of an asset management improvement plan. The agency must provide the TAM improvement effort with resources for the management and implementation of the TAM program, including adequate training for agency staff to ensure sufficient skills and understanding to implement TAM. Clear role descriptions that describe TAM tasks and requirements should be developed. There is likely to be a need

for new skills and qualifications within the agency and training programs in TAM to increase the level of knowledge and skill. [Section 3.4.5.2]

Step 8: Establish Performance Management Standards

Performance-based decision making is one of the core principles of TAM. An agency must be able to demonstrate that they are making progress on established goals and objectives and set goals and objectives tied to measurable metrics; make resource allocation decisions based on these goals and objectives and the funding available using the metrics to guide the decision making; and then demonstrate to its customers the results of the investments. [Section 3.5]

Asset and performance managers have recently focused considerable attention on the difference between output and outcome measures or targets. An output is the quantity of work performed by the agency, such as the number of lane miles paved. Outcomes are the resulting improvements in performance or condition, in areas directly relevant to the public, such as condition, cost, mobility, access, safety, reliability, comfort, convenience, externalities, and risk. Including output measures with outcome measures may provide the best support to the TAM program. [Section 3.5.2]

Benchmarking, the practice of using quantitative measures to compare performance with peers, can be a powerful tool to improve agency performance. It provides a means of sharing best practices and a method of self-evaluation. Comparing important performance measures across agencies can motivate an organization; such a comparison demonstrates what is possible by presenting what an agency's peers have been able to achieve and, to some degree, how. [Section 3.5.5.1]

D. Preparing an Asset Management Plan

A TAMP is now required under MAP-21 for the pavements and bridges on the National Highway System. It formalizes and documents key information, including:

- The strategic outcomes or objectives that it supports.
- The services that the agency delivers now and in the future and why they are delivered.
- The nature of the assets required to deliver the services and their current condition and performance in a form relevant to assessing the achievement of the agency mission.
- Planned asset improvements and capacity expansion in response to future demand, risk, and other trends.
- How the assets will be cost-effectively managed throughout their life cycles.
- Long-term financial forecasts, thus informing program development and budget cycles.
- Planned improvements in asset management business processes, goals, and requirements for resource availability and productivity, and desired future performance resulting from implementation of the plan.

A TAMP can be conceptualized as a "business plan" for an organization which has stewardship responsibilities for an infrastructure network. [Section 4 Introduction]

When thinking about whether or not to develop a TAMP, it may be useful to consider questions such as the following:

- Have we documented the levels of service or performance of the assets that we are providing and researched what our customers' value?
- How do we know whether the agency's mission is being accomplished with maximum effectiveness and efficiency? Do we have the evidence to convince stakeholders of this?
- Do we have an accurate picture of the scope of ALL assets that we manage, their financial value, their position in their life cycle, and the risks associated with the assets?
- Have we considered all the options in developing upgrade and preservation programs? How have we optimized our planned expenditure in asset preservation?
- Do we understand growth and demand for the services provided through transportation infrastructure?

The TAMP is a document which brings all of these together into a single plan (perhaps with multiple references to supporting documents and plans) which tells the story of the agency in relation to its mission. [Section 4.1]

Options for TAMP Structure
There is no "one right document" structure for a TAMP as it will depend on how an agency plans to utilize the document. However, there are real benefits to having a standard TAMP structure, which enables a repeatable and standard TAMP audit and review process and the benchmarking of TAMP sections with other agencies or industry bodies. Table 2 presents a structure for an initial TAMP that is consistent with the International Infrastructure Management Manual (IIMM) recommendations. [Section 4.2.2]

Who Needs to Be Involved?
As Figure 5 shows, the audience for the TAMP can be arranged into concentric rings of involvement. If the asset management leader and steering committee are already in place, then many of those individuals will naturally serve on the core team that does most of the writing of the TAMP. The remainder of the steering committee members would serve as reviewers. If the steering committee and leader are not yet appointed, then it will make sense to appoint TAMP authors who can eventually serve in the implementation roles. [Section 4.2.3]

The Iterative Process of TAMP Development, Review, and Improvement
Practitioners describe the TAMP as a "living" document. As the TAM planning process is repeated on an agreed cy-

cle, the output of that process (the TAMP) will develop, morph, and change to accommodate the agency's increased knowledge and understanding of service levels and performance measures, and how agency policies and programs affect them.

A best practice TAMP should demonstrate:

- Full support and commitment of the agency to TAM and seamless integration of TAM principles into all levels of decision making including, for example, Human Resources, Information Technology, and procurement.
- Well-reasoned service levels that have been debated and agreed with tax payers and service users.
- Evidence that agreed levels of service and performance levels are being achieved consistently.
- Demonstrated knowledge of growth and demand.
- Integration of risk management at all levels of decision making and in all works and financial programs, including maintenance programs.
- Integration of sustainability principles with all decision-making processes and the inclusion of appropriate sustainability projects in the TAMP's program outputs.
- An optimized resource allocation process.
- Coordination of all work programs with those of other utility operators sharing the same corridor to ensure that waste and disruption to customers are both minimized.
- TAMP Improvement programs that are appropriate, resourced, monitored, delivered, and reported on and the results of which are used and incorporated into the TAMP as appropriate. [Section 4.2.5]

Table 2. Recommended TAMP Outline

Section Name	Description of Contents
Executive Summary	• Typically a stand-alone high-level overview of the TAMP, used to communicate the content of the TAMP to elected officials and external stakeholders.
Introduction	• Sets the scene, provides a high-level description of the agency's mission and goals, its role and the roles of other parties, and the purpose of the TAMP. Addresses stewardship and life-cycle management requirements. Has a high-level description of the assets—what they consist of, quantities, financial worth, or value.
Levels of Service	• The agency's mission is broken out into key drivers, transportation services, and levels of service (LOS) or performance measures. • These define the agency's high-level values and priorities, such as safety, preservation, and growth. • The LOS are the yardsticks by which the agency's performance is to be measured and monitored. Identifies relevant stakeholders and key user groups, describes consultation and stakeholder expectations of the services. • Identifies any laws and regulations that impose mandates or constraints on performance or the implementation of asset management. May present strategies to overcome regulatory barriers. • May also identify program needs to close identified LOS performance gaps. • This section also describes the agency's current and desired capabilities to deliver the required services and quantify the measures, and reports current performance quantitatively as a demonstration of existing capability.

Section Name	Description of Contents
Life-Cycle Management	• More detailed information about the assets, including condition and performance summaries, asset life cycles, useful lives, and remaining lives; identifies critical assets. • Life-cycle strategies and management methods for all activities relating to the assets, including operations, maintenance, asset renewals, and new asset development work activities, condition and performance monitoring, risk management practices, procurement, and how the program will be delivered. This will be drawn from the results of life-cycle and risk-based analyses and interpretation and lead into program development and program needs. • An overview of current and desired capabilities in pavement and bridge management and other applicable areas of asset management systems for life-cycle management. • Descriptions of the drivers for each type of work undertaken.
Growth and Demand	• Identifies the drivers and influences of change on the network. Assesses how the anticipated future growth and demand for transportation services will impact the demand for new or better assets and asset maintenance and renewal needs in the future. • May identify program needs to cater to future demand. • Describes demand management strategies as a means of reducing the impact of demand growth on assets. • Also describes the agency's current and desired capabilities to measure demand and growth as they affect asset management processes and investment needs.
Financial Summary	• Brings together all program needs identified in the TAMP into medium- and longer-term financial cash-flow forecasts—to support the more detailed annual budget process. • Financial management policies: GASB34 financial reporting requirements, including projected asset valuation and depreciation, could also be included here. • An overview of funding sources, constraints on the use of funding, long-term funding needs, and other aspects of the budgeting and funding processes that impact asset management.
TAM Practices	• Describes current organizational processes supporting asset management decision making and reports current status of TAM practice in the form of the self assessment. • Describes the information systems and tools used to support TAM. • Describes data needs and quality expectations.
Improvement Plan	• A work plan for improvements to asset management processes in order to move from the current state to the desired state in the agreed time frame, includes a description of risk factors and anticipated problems.
Appendices	• Tables and documentation in support of the preceding sections.

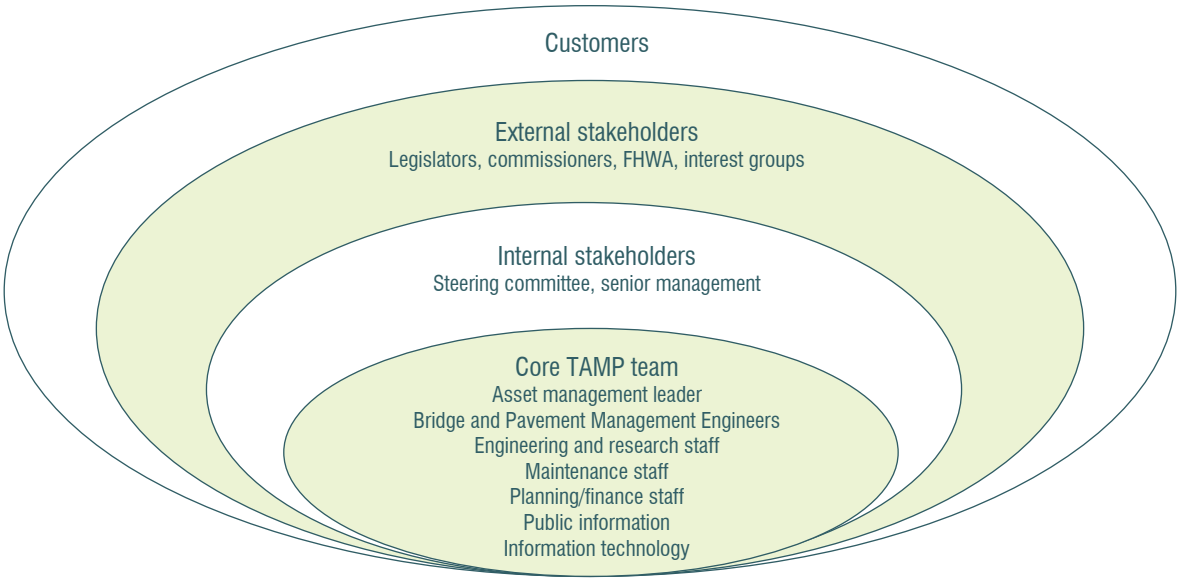

Figure 5. Participation in TAMP Development

The TAMP plays a key role in connecting the agency's corporate strategic direction with implementation tools, ensuring that the agency can achieve its mission in the most cost-effective manner while delivering the required levels of service. [Section 4.3]

E. Processes, Tools, and Data to Support Asset Management

Agency-Wide Strategic Performance Measurement

Good asset management requires that the right information be available to the right levels of the agency at the right time. For each decision maker, the goal of performance measurement is to present that person with information specific to his or her job role and objectives to tell about current performance and the effects of prospective decisions on future performance.

Effective asset management naturally requires knowledge of the assets being managed. The quality of project selection, trade-off analysis, and resource allocation decisions are directly related to the quality of the information upon which they are based. Quality asset data are also a key input to a quality TAMP. Since data collection is a significant asset management cost, it is only prudent to cast a critical eye on the cost and value of data gathering processes. [Section 5.1]

Management Systems and Performance Measures

Agencies typically procure pavement and bridge inventory and management systems as part of the Awakening stage of the maturity scale. Initially, the systems may be used only for inventory collection, data management, and special investigations. From a long-term perspective, if the agency wishes to continue to advance in maturity, it should select a management system able to continue to support agency business processes as it grows. [Section 5.1.2]

Mission performance measures, also called outcome measures, are determined by the agency's strategic goals and objectives, and generated by the agency's monitoring processes. They quantify how well the agency is accomplishing its mission. Generally, these measures respond directly to the concerns of road users, taxpayers, and other stakeholders outside the agency. Because agency performance, asset performance, and condition measures are commonly called "performance measures," it is easy to confuse them in conversation and reports. There is no simple way to avoid this, so care must be taken to ensure that meanings and subjects are clearly understood.

Performance measures describing aspects of agency mission are rarely reported from raw data, but instead are aggregated and otherwise transformed to make them most useful for their intended purposes. Common applications of these data are

- Snapshot reporting of current performance.
- Comparisons among parts of the network, identifying the strongest and weakest parts.
- Trend analysis, showing how performance has recently changed in different parts of the network.
- Predictive analysis, showing how condition and performance might change in the future.

All of the above are often published on a website for public information. This is often done to build confidence that the department knows what is going on, and it also helps members of the public and stakeholders build some context on how weather, special events, economic conditions, and incidents that they may have experienced relate to network-level performance.

Internally, these types of reports are useful to management, usually at a greater level of detail, to spot current problems and build an intuitive feel for causal factors to help diagnose problems. The information is often used for resource allocation. Analysts may mine the data in order to discover and diagnose performance issues. [Section 5.1.3]

On July 6, 2012, President Obama signed into law P.L. 112-141, the Moving Ahead for Progress in the 21st Century Act (MAP-21). This act established national performance goals for Federal highway programs, including:

- Safety
- Infrastructure
- Congestion reduction

- System reliability
- Freight movement and economic vitality
- Environmental sustainability
- Reduced project delivery delays

The *AASHTO Transportation Asset Management Guide—A Focus on Implementation* includes the following performance measures:

- Condition
- Life-cycle cost
- Safety
- Mobility
- Reliability
- Customer measures
- Externalities
- Risk

Table 3 provides a reference comparing these newly created MAP-21 performance measures with those included in the *AASHTO TAM Implementation Guide.*

Table 3. MAP-21 Measures Compared to TAM Guide Measures

MAP-21 Measure	TAM Guide Measure
Safety	Safety
Infrastructure	Condition
Congestion Reduction	Mobility
System Reliability	Reliability
Freight Movement and Economic Vitality	Mobility and Reliability
Environmental Sustainability	Externalities
Reduced Project Delivery Delays	Mobility and Reliability
	Life-Cycle Cost
	Customer Measures

Condition
Condition relates to the structural integrity of an asset. Condition can be measured visually or with instruments and over time condition will almost always deteriorate without agency intervention.

At the agency mission level, condition information should be expressed using uniform definitions across all assets. As condition information at this level is primarily for use by customers and external stakeholders, it should be expressed in non-technical terms using words that are meaningful to them. [Section 5.1.3.1]

Life-Cycle Cost
In a pure asset management context, the term "life-cycle costs" includes all of the costs that an agency incurs in managing assets from the creation of the asset to its ultimate disposal. Life-cycle costs are currently not often used

for public information purposes because of the difficulty of explaining how they work. However, because they represent the agency's long-term responsibility to keep costs minimal and are the primary justification for state-funded preventive maintenance programs, they can be important to legislators and certain interest groups. They are very important as mission indicators for internal management purposes, especially for planning of preventive maintenance programs. [Section 5.1.3.1]

Safety
Safety is an important aspect of an agency's mission and asset management decisions have a major impact on safety. These are important, but certainly not comprehensive, measures of safety. Every transportation network contains safety features specifically meant to reduce the frequency or severity, or both, of crashes. Measuring and tracking their effectiveness is a need that is unevenly met in the current state of the practice. [Section 5.3.3]

Mobility
Mobility is considered to be one of the primary justifications for having a transportation network. A common way of measuring mobility, using a broad definition of it, is origin-destination (O-D) travel time.

Transportation planners compute O-D travel times by link, trip purpose, time of day, and season as a part of facility planning. This usually provides sufficient detail for asset management purposes. As a means of tracking agency performance for public consumption, a single network average trip time on a particular class of road is usually sufficient. Senior management will typically want more detail, such as peak hour trip times by corridor, as a way of identifying emerging needs for new capacity. [Section 5.1.3.4]

Reliability
In an asset management context, reliability is closely related to mobility and is defined as the standard deviation of origin-destination travel time. This definition is used because it is compatible with all types of modes and system components. Reliability can be improved by adding capacity, by responding more effectively to incidents, and by improving system operations management. [Section 5.1.3.5]

Customer Measures
When asset management is placed in a framework of political accountability, as it must be for successful implementation, then it must consider aspects of performance that are important to the public but may have no discernable impact on agency operations. Comfort/convenience is a collective term for the subjective impressions of transportation system users, that affect their satisfaction with the system separately from the other performance measures described here. [Section 5.1.3.6]

Externalities
Externalities are the effects of transportation facilities and operations on non-users of the system. The issues in this category typically include:

- Air pollution,
- Water pollution,
- Noise pollution,
- Community severance,
- Effect on community image and property values, and
- Economic impact of land use. [Section 5.1.3.7]

Risk
Risk management is an important part of asset management, especially at the Proficient and Best Practice stages of maturity, although it should also be present in the Structured stage. However, there are few practical tools yet available in the marketplace, with many practitioners managing this aspect with the aid of spreadsheets or custom built databases. Risk is the threat to transportation operations caused by extreme events, other external hazards, and from asset failure arising from any cause. Some examples of causes of asset failure are poor condition, unexpected load-

ing, or poor work practices. Asset criticality is a key concept, relating to the importance of the asset and the level of risk that it may be exposed to. Criticality can be a driver of data collection efforts. [Section 5.1.3.8]

Combining Dissimilar Performance Measures

In many asset management applications, there is a need to combine dissimilar performance measures, including any or all of those listed earlier in this section, in order to develop a scale that can be used for comparing and prioritizing alternative investments. Two methods are very commonly used:

- **User cost**, which converts each performance measure into equivalent quantities of money and then combines them;
- **Utility**, which establishes a unit-less common scale for each performance measure and then combines them. [Section 5.1.3.9]

Management Metrics

Agencies that are more mature in their asset management processes have procedures to monitor the quality of their collection and updating processes and to use this information in planning data and process improvements. This is very important at all levels of asset management maturity and essential at the Best Practice level of maturity. Examples of evaluation metrics include:

- Data quality measures such as statistical variance and consistency checks;
- Missing value checks of required data items;
- Manual spot checks of data;
- Planning, status, and history of quality assurance reviews;
- Requests for additional functionality;
- Measures of response time from support staff; and
- Trends of agency mission performance outcomes compared to resource inputs. [Section 5.1.6]

Inventory

The inventory of transportation assets provides a data infrastructure to tie together the various data sets required for a comprehensive, mature asset management process. In addition to the performance information described above, asset management requires the following types of data for every type of asset:

- Geographic location, including route/milepost, a linear referencing system if separate from route/milepost, latitude/longitude, and corridor definitions.
- Jurisdiction data, such as district and administrative subdivisions of the department, county, municipality, political districts, ownership, and maintenance responsibility.
- Functional and utilization data such as functional class, number of lanes, speed, and tolling; presence of curbs, sidewalks, and other user features; special-purpose networks such as the National Highway System, the Strategic Highway Network, and freight networks; presence of school bus and transit routes; and presence of utility lines.
- Performance characteristics such as access restrictions, roadway geometry, obstructions, medians, and safety features.
- Construction history and historical significance.
- An archive of valuable documents, often a multi-media file repository. [Section 5.1.7]

Linking Strategic Performance Measures to Levels of Service

Many aspects of asset management are bottom-up activities in that they involve collecting substantial amounts of data and processing them into smaller but more useful quantities of information that are communicated upward and further condensed through the organization. Most of the sections of this chapter are concerned with implementation of this upward data flow and information processing.

However, the various data collection and processing activities must be guided by a coherent strategic vision that specifies what goals and objectives are to be served and what measures will quantify the objectives. Asset management requires a common agency-wide system of standards and definitions that guide the various business processes. This guidance is top-down. [Section 5.2]

Using Strategic Plans to Develop Agency Goals

The strategic importance of the delivery of transportation services by the agency means that the direction for the levels of service must be set at corporate level and applied throughout the agency's processes, procedures, and service delivery mechanisms. These strategic statements are less detailed than the tactical requirements of the TAMP, and less detailed than the contracts and standard operating procedures and processes that flow from it. Nevertheless, there must be a continuum of intent, and of service or purpose, which can be traced upwards and downwards through the hierarchy of level of service statements.

Although the mission of many state DOTs is set out in state law, the process of strategic plan development will normally include development of vision, mission, and corporate values statements that establish the long-term desired position of the agency and how the agency wishes to conduct its affairs to achieve its objectives. It produces a clear statement of strategic direction, policies, risk management, and desired outcomes.

Strategic plans typically have a 10- to 25-year planning horizon, which is often based on practical financial management considerations.

Because the service lives of the assets are often much longer than the strategic plan's horizon, the implied longer-term visions are important. Without them, the asset managers would not be incorrect in designing and maintaining the assets with a desired end of life at the end of the strategic planning period.

Strategies produce very-summarized visions and goals. They are therefore supported by more specific objectives that are used to ensure that the goals can be achieved and by targets that measure progress towards that achievement.

The relationships among the various drivers, processes, documents, and achievements are represented in Figure 1-2 in the *AASHTO Transportation Asset Management Guide—A Focus on Implementation*. It shows the position of the TAMP as the key in linking the strategic outcomes desired by the agency with the establishment of achievable, shorter-term plans and delivery of transportation services. It also illustrates, through the inclusion of the Annual Report and its inputs, the importance that the TAMP and its associated processes have in achievement of the corporate objectives.

An agency is likely to have a number of related strategies, such as growth management, improving operational efficiency, increasing roadway safety, addressing mobility, and implementing walking and bicycling enhancement projects to support its overall strategic plan. The linkages between these strategies and the TAMP are essentially no different from those for the main strategic direction, and the TAMP has a major role in coordinating and managing the conflicting needs and timings and bringing them together. [Section 5.2.1]

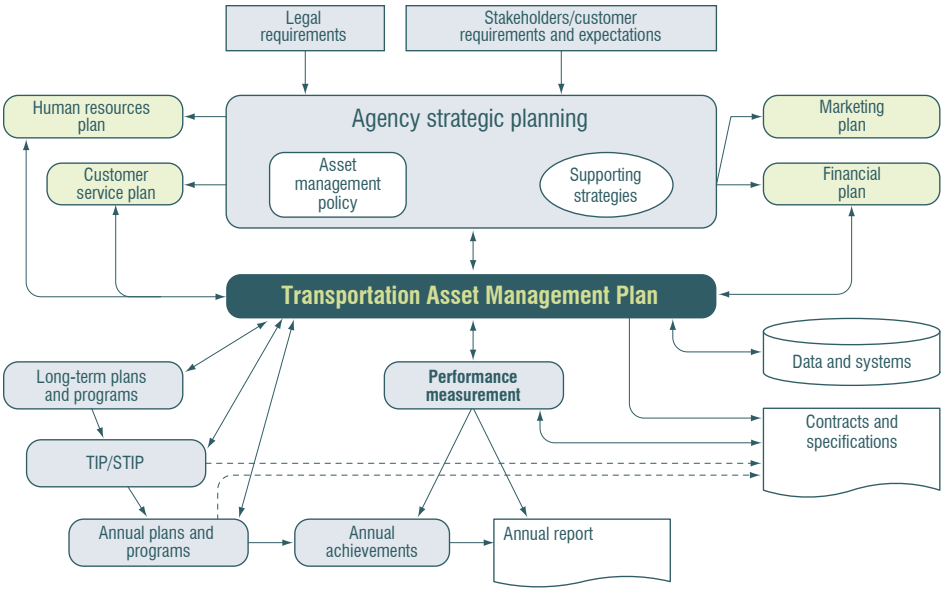

Figure 5. Participation in TAMP Development

Understanding Customers and Users

"Customers" is sometimes used to refer to consumers of the services provided by an agency and "users" to those who use the network assets. However, there is in effect no significant difference between these two groups of people, especially when discussing transportation networks. The term "customer" is used here to refer to both groups.

Developing agreeable levels of service will be assisted and simplified by understanding customer needs and wants. Understanding how customers define and think of the levels of service delivered by transportation networks can provide a useful indication of the levels of service that should be developed. It is very easy for transportation system agencies, managers, and engineers to concentrate on delivering levels of service that they think the customers want, rather than those that are important to them. This can be measured using the conventional techniques of marketing research. [Section 5.2.2]

All those who use the transportation network can be considered customers, but within this broad grouping of people and organizations, there are a range of different needs, values, and expectations. In some contexts, customers and stakeholders are the same—everyone—but in other contexts they are different, and customers can be stakeholders but stakeholders may not be customers. There are three broad categories into which users and customers are usually segmented, because of their different needs, expectations, and relationships with the agency, namely:

- **Customers**—Anyone who uses any part of the transportation network, who is affected by the activities associated with providing the service, or who has a legitimate interest in it.
- **Stakeholders**—Tend to have a greater interest in what happens on the network than the average customer does, they can also differ from customers in that their interest in the transportation system is institutional rather than merely personal.
- **Partners**—A type of stakeholder which shares strategic objectives with the transportation agency. Partners may assist in the delivery or funding of projects. [Section 5.2.2.1]

Understanding what customers value is key to developing a practical and useful system. Value has been defined as the difference between benefits and costs. For example,

Value = benefits – costs

In this context, benefits can be thought of as any feature provided by the asset or service that the customer believes will solve a need or problem they have. In broad terms, if the perceived benefits (of an asset) exceed the costs of that asset to the customer, then it will be perceived to have value, and the customer is likely to be happy. However, if the perceived benefits are less than the perceived costs, then the customer will usually be unhappy. [Section 5.2.2.2]

Developing Levels of Service

Levels of service (LOS) are classifications or standards that describe the quality of service offered to road users, usually by specific facilities or services against which service performance can be measured. All services delivered by the network should be covered by agreed LOS, although it may take some time to achieve this goal. Achievement of LOS is determined by performance measures. At the early stages of TAM maturity, some agencies use their performance measures as LOS statements. LOS achievement is typically measured at a more detailed level than agency mission, although the more important LOS measures may also be reported at the higher level. At the Proficient level of TAM Maturity, LOS are normally split into two distinct categories: customer and technical.

Customer LOS relate to how the customer receives the service in terms of tangible and intangible measures or criteria. They are expressed in terms that customers can understand and comprehend. Tangibles include the appearance of facilities, frequency of service disruptions, availability of service, frequency of crashes, etc. Examples of intangibles include speed of service, staff attitude, and ease of dealing with the agency.

Technical LOS support both the customer's and the agency's strategic objectives. They are usually expressed in technical terms used by agency personnel or contractors.

LOS should be based on specific service criteria, e.g., quality, capacity, accessibility, mobility, reliability, comfort, safety, etc. Targets can be set for each measure.

Because levels of service are developed from the mission and goals of an agency, they should cover all of the asset groups that contribute to the delivery of the service. These include the visible assets, such as pavements, bridges, lighting, and signs as well as those which might be less visible or less apparent in terms of being important to users, but are vital in providing service. For example, effective drainage minimizes the risk of flooding and guardrails provide an important safety function.

In the way the level of service term is being used here, it can include any aspect of asset performance affecting any stakeholder. It can be used very broadly to include service to stakeholders in their roles as users, taxpayers, partners, elected officials, and community residents.

Levels of service should be developed in a hierarchy that reflects the increasing level of detail of planning activities as they progress from strategic to tactical and operational. Figure 6 illustrates some of the strategic and tactical points where levels of service help guide decision making. [Section 5.2.3]

Public Involvement Approaches to Level of Service Development

Developing appropriate and meaningful levels of service that link to the agency's strategic objectives is a process which requires technical, financial, and market research inputs.

The first step involves market research thinking—finding out what customers and users think about the service and what their service preferences are.

Gaining feedback from customers and users can be achieved using different methods, some of which provide quantitative statistical information, while others are more qualitative and subjective and can result in skewed results. Obtaining an accurate cross-section of views requires a carefully considered approach representative of the "population" which uses or is affected by the service.

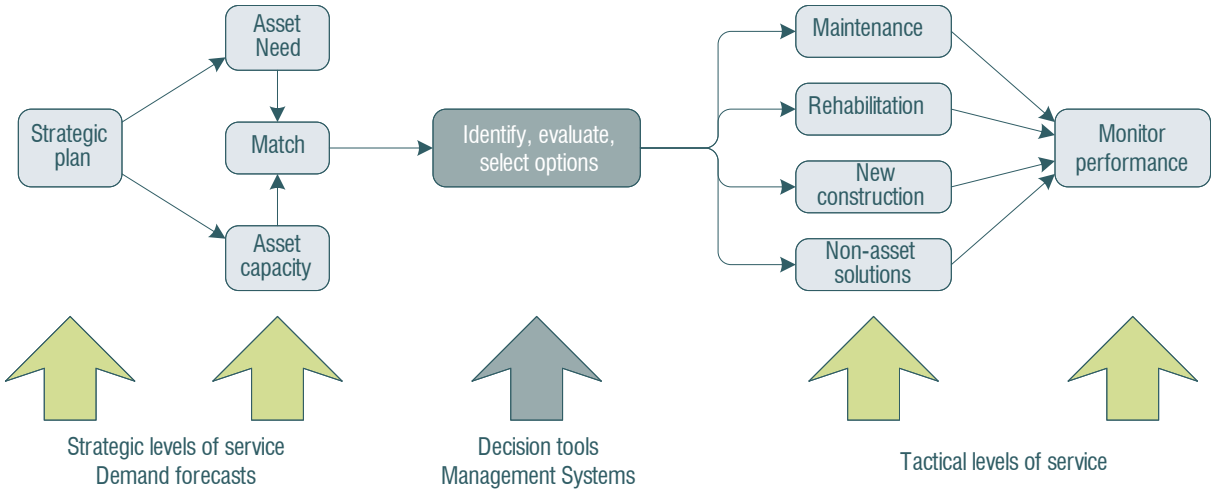

Figure 6. Levels of Service

Techniques for gathering input from customers and users include:

- Community forums and public meetings.
- Meetings with key interest groups.
- Self-completion surveys and questionnaires.
- Market survey research.
- Focus group research.

In establishing a consultation process around levels of service, it is important to consider what method to use in relation to the audience as well as the cost of the research. It is also important to consider how the information will be presented and used in making decisions about particular levels of service. [Section 5.2.3.3]

Integrated Levels of Service

With information about customer expectations and preferences, the next step is to develop linking statements which relate the agency's high-level objectives to the specific outcomes that customers seek. Measures relating to "customer" and "technical" levels of service can then be developed. The "technical" measures should be in a form that is suitable for inclusion in maintenance delivery contracts or internal service agreements. An example of linking strategic objectives to levels of service is provided in Figure 7. [Section 5.2.3.4]

Levels of Service and Performance Measures

The levels of service established using the procedures outlined previously can be considered to be a set of standards, and like any standards, their achievement should be measured and tracked. As achievement of a standard is often called performance, it is relevant to distinguish between the condition and performance of an asset:

- An asset's performance is directly related to its ability to provide the required level of service.
- Its condition is an indication of its physical state, which may or may not affect its performance.

An asset can fail through either inability to perform adequately or inadequate condition. Performance of an asset can usually be measured in terms of availability, reliability, capacity, and delivery of other agreed levels of service, whereas condition is measured by factors such as cracking, scabbing, potholes, loss of friction, and roughness.

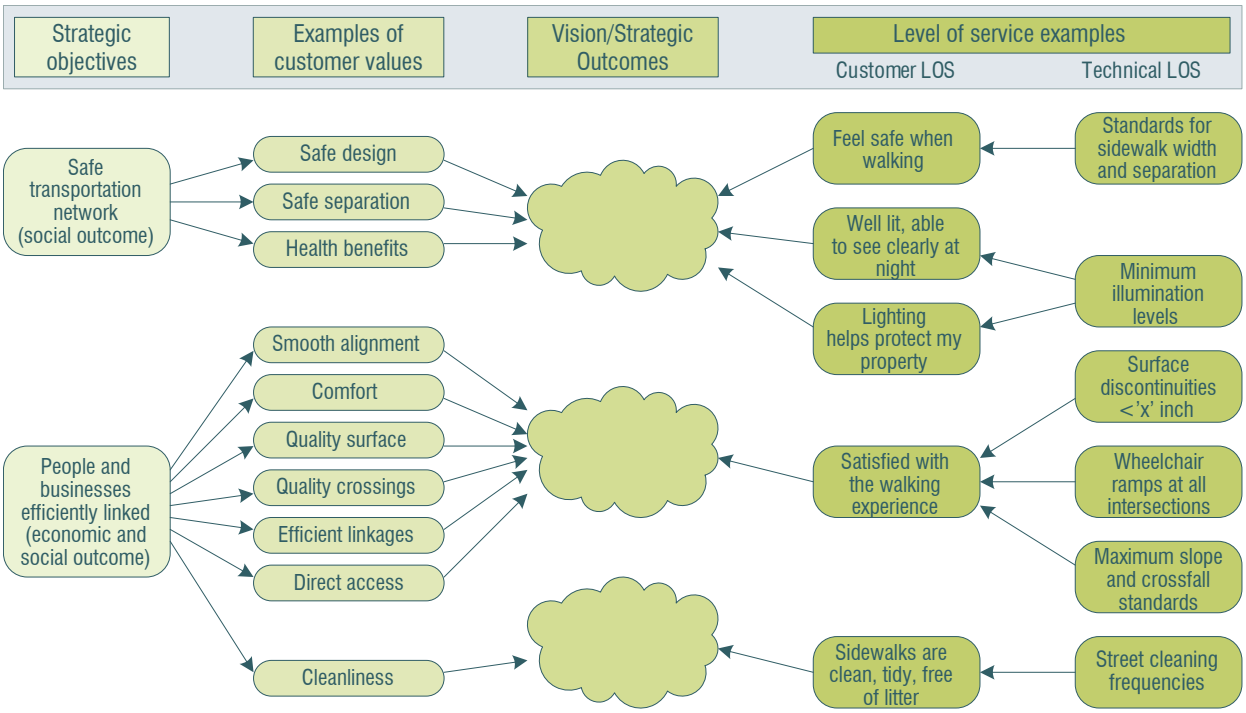

Figure 7. Linking Strategic Objectives to LOS

Performance measures and levels of service should be linked: level of service supported by a performance measure, and a performance measure derived from a level of service, as outlined in Table 4. The process for developing levels of service is discussed in Section 5.2.3 of the *AASHTO Transportation Asset Management Guide—A Focus on Implementation*. [Section 5.2.4]

The following points will help in developing useful and affordable performance measures:

- Every measurement costs money. Minimize the amount of new data required and maximize the use of data already collected.
- Some measures that appear useful may be impractical because of the cost of data collection.
- Performance measures, like levels of service, must be SMART (i.e., specific, measurable, achievable, results-oriented, and timely).
- Performance measures must be meaningful to the target audience.
- It is often easier to define a performance measure and track it over time if it is tied to a level of service standard, provided the level of service definition remains constant.
- When possible, a level of service standard should be expressed in terms that describe the user experience when using the facility. [Section 5.2.4.1]

NCHRP report 632 (National Cooperative Highway Research Program, 2009) describes a framework for applying asset management principles and practices to managing Interstate Highway System (IHS) investments. [Section 5.2.4.2]

Growth and Demand Forecasting

Having established what the agreed levels of service are, providing them for current customers is a matter of gap analysis, prioritization, and resource allocation. However, providing the agreed levels of service for future customers requires knowledge of who they may be and their needs. This requires consideration of the likely effects of changes

in population (growth or decline), land use (e.g., agricultural to residential), and consumption patterns (e.g., changes in auto occupancy). The end results are changes in the number or size, or both, of the agency's assets and facilities or the levels of service it delivers.

Long-range transportation planning is a key input not only into the agency's forecasts but also into the growth and economic forecasts of the state, counties, and municipalities. [Section 5.3]

Table 4. Examples of Level of Service and Performance Measures

	Customer Level of Service	Technical Level of Service	Performance Measure
Tangibles	• Extent and size of potholes • Clarity of signage • Night-time visibility • Ride comfort at 55 mph	• Maximum size and time to repair • MUTCD standards • Minimum illumination levels on roads—by hierarchy • Roughness (IRI)	• Number of complaints about potholes • Road users and pedestrians satisfied with signage (%) • Residents satisfied with street-lighting (%) • Smooth Travel Exposure
Reliability	• Levels of congestion • Number of signal break-downs	• Level of service A to F • Number of signal break-downs and time to repair	• Average duration of rush hour trip from A to B • Outages/year. Maximum and average duration
Responsiveness	• Response time to breakdown or incident	• Response time to breakdown or incident	• Maximum and average times

State DOTs carry out their long-term network planning and prioritization in accordance with legislated requirements, producing Long-Range Transportation Plans (LRTP) and Statewide Transportation Improvement Plans (STIP). Asset management processes can contribute to long-range planning by identifying mobility and capacity needs, and (when asset management is used to its full capability) identifying new preservation needs that are generated by the delivery of new infrastructure.

An agency's procedures for developing its LRTP and STIP are not replaced by asset management; rather, TAM ideas, data, and tools can help shape the LRTP and STIP by:

- Linking agency resource allocation to policy objectives,
- Defining the levels of service to be achieved,
- Identifying strategic investment choices and evaluating and analyzing trade-offs among them at the appropriate stages, and
- Providing the information and analyses to facilitate the appropriate resource allocation decisions that follow good TAM practice. [Section 5.3.1]

Transportation growth forecasts always have considerable uncertainty due to unknown variations in economic climate, economic development patterns, success of local employers, and land owner decision making. These uncertainties carry down into asset management in the form of uncertainties in utilization, deterioration, cost, and expansion. [Section 5.3.2]

Generally, a TAMP should not ignore uncertainties, but instead should describe the contingencies surrounding significant causes of uncertainty. The TAMP should also recognize and discuss the implications of associated risks. In some cases, the future direction will be totally unknown and no legitimate assumption can be made. If there are potential risks associated with the assumptions, then these should be stated and the implications identified. [Section 5.3.2.2]

Asset Planning and Improvement Strategies

With an understanding of growth and future demand trends, and the impacts on levels of service, an agency can make more informed decisions on how to address future deficiencies or shortfalls in service. This may require capital investment in new works involving newly created or expanded assets, or consideration of a range of "non-asset solutions" (demand management). [Section 5.3.3]

Often, the level of service and performance requirements of a transportation system can be met by solutions other than new construction. In situations where management and operational activities or treatments are legitimate alternatives to new construction, it is desirable to include these actions in an agency's broad "toolbox" of asset management solutions. [Section 5.3.4]

For example, options for reducing congestion in the central business district of a city might include building new arterials or building a bypass to take through traffic away from the area. But lower-impact solutions are also possible, such as improving public transit service, imposing parking restrictions, or collecting a toll for access to the area.

The non-asset based solutions provide for the possibility of meeting a level of service demand more cost-effectively by: improving a competing or complementary facility or mode, reducing demand to a level that can be served by the existing infrastructure, modifying the level of service to one that can be satisfied by the existing infrastructure, or a combination of these. [Section 5.3.4.1]

Risk Assessment and Management

Risk management is a process of identifying sources of risk, evaluating them, and integrating mitigation actions and strategies into routine business functions of the agency. Risk is associated with uncertainty. Risk management should be viewed as a core business driver influencing all activity and not as an isolated, add-on process. Integration of risk management into asset management is relatively new, and has focused thus far on bridges and tunnels. However, all types of transportation assets have uncertainty and risk factors associated with them. It must be remembered that the risks associated with individual assets translate immediately into risks for the agency, and the consequences and effects of all risk events must therefore be considered at the agency level, too.

In common practice today, risk in asset management is assessed as vulnerability to natural and manmade hazards, as discussed in Section 5.4.1 of the*AASHTO Transportation Asset Management Guide—A Focus on Implementation*. The assessment is typically conducted in three steps:

1. Likelihood of an extreme event, expressed as a probability, or range of probability, of an event such as a flood, earthquake, asset failure, or other risk driver.
2. Consequences to the asset, a categorization of the damage or loss of function of the asset, conditional on occurrence of an event.
3. Effect on mission, life, property, and the environment, a categorization of the effect on the agency, the public, users, and non-users, of the asset damage or loss of function caused by the extreme event. [Section 5.4]

Sources and Types of Risk

There are many potential sources of risk to a transportation agency. These can be grouped into four major areas:

- **Natural events and hazards:** These include floods, snow storms, extreme wind, wildfire, landslide, tsunami, and earthquake. While probabilities and return periods of these events may be understood, it cannot be predicted when exactly the next event will occur. These events cannot be controlled, although an agency can prepare and mitigate against the effects in advance.
- **External impacts on the agency:** These include the failure of other parties or organizations to provide a service or product upon which the transportation agency depends. Examples can include the supply of power for traffic signals, lighting, or other automated highway controls, or the supply of materials which are deficient in some way.

- **Physical asset failures:** These events are caused by poor or deteriorating condition or performance of an asset or asset component, leading to disruption to users or adverse effects on the environment and the need to undertake remedial work. Certain types of failures may occur suddenly, such as fracture of structural steel. Other events can be better predicted through the use of condition and performance monitoring programs and predictive modeling tools.
- **Operational risk events:** These events include vehicle operator errors such as impact of a vehicle with a structure; vehicle equipment failures that cause fires or collisions; failure of safety features of the transportation system, such as lighting, traffic signals, or railroad crossing gates; or intentional damage. It may also include errors made within an organization, such as management decisions or design errors. [Section 5.4.1]

How to Apply Risk Management as a Core Part of TAM

Risks can be described in monetary (quantitative) or descriptive (qualitative) terms and used as performance measures and levels of service in much the same way as other performance concerns. Risk can be used in a variety of tasks, such as priority setting and resource allocation decisions, as well as in routine tasks such as setting intervals for asset inspection. A typical risk management framework is illustrated in Figure 8. This systematic process can be used for a wide variety of activities within an organization, ranging from specific projects to corporate management.

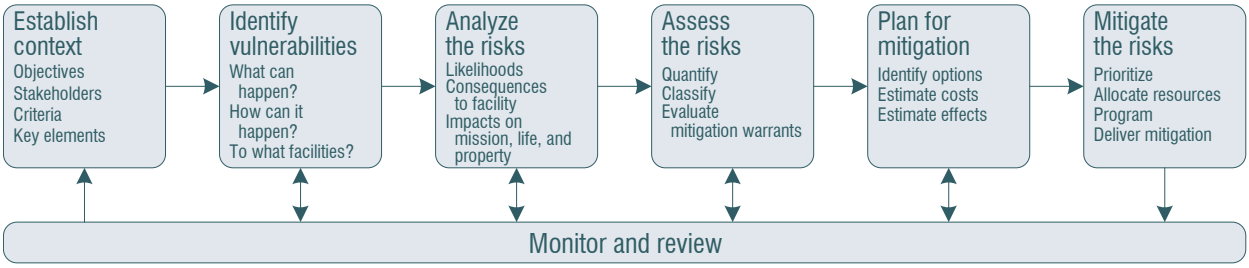

Figure 8. Typical Risk Management Framework

Agencies can differ in how they define risk. Most agencies would consider catastrophic natural hazards to be a part of the framework. Some might include vehicular crashes and loss of function due to deterioration, while other agencies might exclude these. Sabotage and terrorism are part of the risk framework for some agencies but not others. So the first step is to define the objectives of the risk management program and decide what hazards and facilities are within its scope.

A useful way to categorize risk is according to the extreme event, or hazard, that causes the risk. In most cases, agencies will consider risk to be a result of hazards that are somewhat predictable on a large scale, such as the return period of heavy storm events; but not predictable at the facility level. Facilities are classified according to their vulnerability to these hazards. For example, a bridge over a waterway might be vulnerable to scour, while a bridge in an upland area would not.

Each facility is rated according to the likelihoods of the extreme events to which it is vulnerable, the consequences of the event to the asset, and the impact of asset damage on the public. The ratings may be scalar (for example, probabilities between 0 and 100 percent) or categorical. Figure 9 shows how a set of categories might be presented.

It is typical to calculate a risk assessment score based on likelihood, consequence, and impact. This score is used for several purposes: to compare with risk mitigation warrants (e.g., "perform a seismic mitigation action if the seismic security score is less than 50"); to prioritize mitigation actions; and to express the forecast outcomes of the actions. It is not uncommon to express the risk score in categories, such as low, moderate, high, and extreme as in Figure 9. It is also not uncommon to define levels of service to represent a combination of risk classification and warrant (e.g., a set of bridge characteristics in which a longitudinal restrainer is required). Agencies can apply mitigation actions to modify the likelihood, consequence, or impact of the risk. [Section 5.4.2]

Risk Identification and Treatment

Identification of risks may be through internal workshops or by individual contributions from staff members, stakeholders, or other parties. It is important to make sure that there is an ongoing review process to detect changes in hazards and vulnerabilities.

Risk assessment factors should be stored in the asset inventory and categorized as to their source and the type of risk exposure to the organization. How risks are categorized and managed within this framework will depend on the scale of the organization and the potential seriousness of each risk.

	Consequence				
Likelihood	Insignificant	Minor	Significant	Major	Catastrophic
Very Rare	Low	Low	Low	Moderate	High
Rare	Low	Low	Moderate	High	High
Seldom	Low	Moderate	Moderate	High	Extreme
Common	Moderate	Moderate	High	Extreme	Extreme
Frequent	Moderate	High	High	Extreme	Extreme

Figure 9. Risk Likelihood and Consequence Categories

A systematically completed risk assessment process can be expected to provide an agency with a range of vulnerabilities or risk exposures and relative priority ratings, as well as a comprehensive risk management plan, which describes how the risks will be managed. The priority ratings should be influenced by "asset criticality," a measure of how important an asset is in delivering service to the agency's customers.

All organizations manage some assets that are more critical than others. This may be because an asset is a unique link, or because the performance of many other assets (perhaps including other networks such as water supply or telecommunications) are dependent on it, or because of the safety benefits the asset delivers, or because so many users depend on it, and so on. Therefore, the risk identification process should also identify the critical assets, those where the consequences of possible failure are high.

Planning for risk reduction is an important asset life-cycle activity. Section 6.3.4 of the *AASHTO Transportation Asset Management Guide—A Focus on Implementation* describes how the assessment of risk exposure can be included in the analysis of project or asset treatment options. It is also important to identify the most important risks in the TAMP, and how the agency intends to address them. This may be through its operational program, asset preservation program, or new investments which must compete for funding with other priorities. [Section 5.4.3]

Asset Inventory, Condition Assessment, and Performance Monitoring
Asset management requires the following types of data for each type of asset:

- Geographic location, including route or milepost, linear referencing system, latitude and longitude, and corridor definitions.
- Jurisdiction data, such as district and administrative subdivisions of the department, county, municipality, political districts, ownership, and maintenance responsibility.
- Functional and utilization data such as functional class, number of lanes, speed, and tolling; presence of curbs, sidewalks, and other user features; special-purpose networks such as the National Highway System, the Strategic Highway Network, and freight networks; presence of school bus and transit routes; and presence of utility lines.
- Performance characteristics such as access restrictions, roadway geometry, obstructions, medians, and safety features.

- Construction history and historical significance.
- An archive of valuable documents, often a multi-media file repository.

A core function for TAM information systems is to provide access to this information for needs assessment, prioritization, work planning, and analysis. [Section 6.1]

TAM inventory systems can be used to record a wide range of relevant data on the network, including the previous list. In order to manage data collection and management costs and data quality expectations, attributes for which data are collected must be based on asset-specific business needs: such as size, type, material, warranty, descriptive information, etc. For many agencies, another key issue is connecting the different databases that are used. [Section 6.1.1]

Conditions and Functional Performance

Functional performance of the asset describes its ability to deliver the required level of service and can be measured in terms of criteria such as reliability, availability, capacity, and meeting customer demands and needs. Condition describes the physical state of the asset, which may or may not affect its performance. [Section 6.1.2.1]

Asset managers should operate systems to monitor asset condition and performance to:

- Identify those assets which are under-performing.
- Predict when an asset is expected to fail to deliver the required level of service.
- Ascertain the reasons for performance deficiencies.
- Determine what corrective action is required and when (e.g., preservation, rehabilitation, replacement).
- Record asset failures for use in advanced asset management techniques.

As with other asset data, it is also important to periodically review data collection techniques to determine if they are appropriate to current and anticipated business needs. [Section 6.1.2.2]

Life-Cycle Asset Management

Good TAM goes well beyond looking after the physical assets in the highway network; it includes the management of the often intangible aspects of the network's operation, such as the safety of users and highway workers, mobility, reliability, and increasingly environmental effects of road use including greenhouse gas emissions.

Life-cycle planning should consider such wider issues at all stages. Questions to ask could include:

- How will decisions about work practices affect the safety performance of the asset? For example, should pavement surface texture limits be changed, should road-markings be painted more often?
- What allowance should be made for climate change when designing a new asset or facility with a long life? For example, should expanded storm water drainage capacity be provided, should route planning decisions consider the risks of sea level changes in coastal areas? [Section 6.2.1]

The stages of an asset's life considered in life-cycle management planning and implementation are:

- New construction
- Preservation
- Operations
- Replacement
- Functional improvement
- Disposal

Figure 10 presents a typical model of the asset life cycle. [Section 6.2.2]

Opportunities for life-cycle cost reduction are typically greatest in the planning stage, where approximately three-quarters of the factors affecting life-cycle costs are decided. Figure 11 contrasts the total accumulated life-time costs of a typical asset with the opportunities for life-cycle cost reduction.

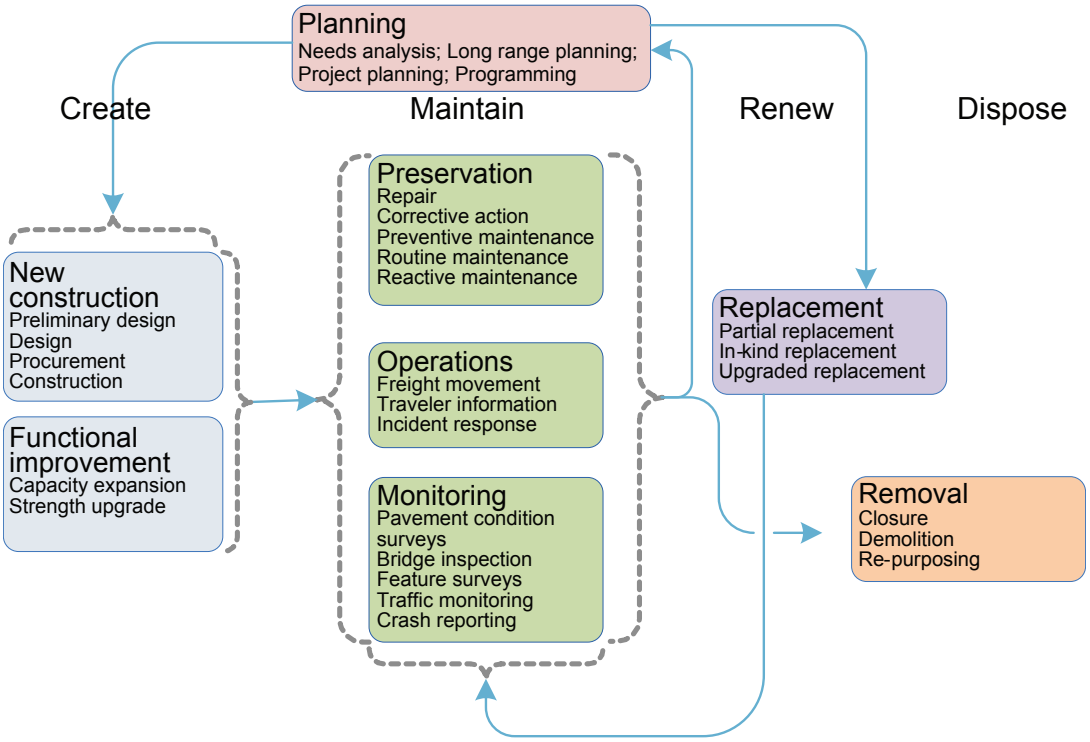

Figure 10. Asset Life-Cycle

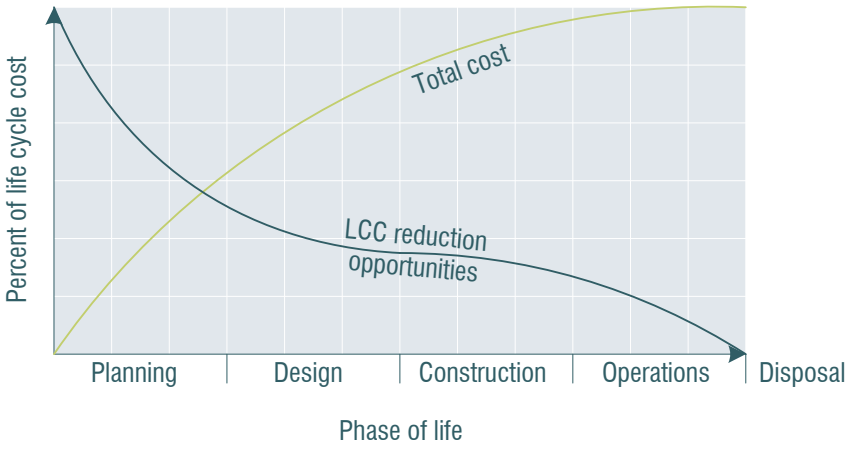

Figure 11. Asset Life-Cycle Cost—Decision-Making Opportunities

It can be seen that the greatest opportunities for reducing the life-cycle cost are at the beginning of the project—scoping, option evaluation and selection, etc.—and these opportunities reduce as the asset moves through its life cycle. Once the asset is built, the focus then becomes managing and maintaining it in the most cost-effective manner, doing the right work at the right time to get the best value for money in terms of the services that the asset delivers. [Section 6.2.8]

Models

An agency that is proactive in asset management preservation does not simply anticipates it and finds the best place in a facility life cycle to intervene, to minimize costs and maximize mission performance measures over the long term.

Deterioration and life-cycle cost models are typically built into most pavement and bridge management systems. It is not enough, however, to have software able to make forecasts. Routine business processes of the agency must make use of the models to plan future work, optimizing the timing of work to best accomplish the agency mission. But an agency will not rely on deterioration models unless the models reflect the best available understanding of deterioration of the agency's own assets. It is necessary to continue to monitor actual deterioration in comparison to forecasts, and use this information to improve the models.

Increasingly, long-term programs are needed, not only for effective life-cycle management of assets, but also in negotiating funding needs with Federal and state agencies. [Section 6.3]

The primary value of forecasting models is that they allow decision makers to quantify how their decisions might affect mission performance measures. Typically, with computer-based models, the processes and methods involved are equally applicable to manual and PC-based analysis. The need for this kind of feedback exists at many levels of the organization:

- Funding bodies like to know how a requested funding level will affect performance of the transportation system as a whole. Will it require more funding to maintain current performance? Will an improvement in one area cause a decline in another area?
- Program managers want to know which projects gain the greatest improvement in performance relative to their cost.
- Maintenance planners want to know how much planned and unplanned maintenance to undertake, and on which facilities, to have the biggest effects in reducing future costs. [Section 6.3.3]

"Optimized Decision Making" (ODM). ODM principles can be equally applied to asset preservation and replacement optimization, and optimization of new construction projects and improvements. ODM is a suitable approach to making decisions across different funding allocation processes.

Multiple benefits can accrue to an agency using a decision support methodology for project selection and priority setting, such as ODM, including:

- Extension of asset life.
- Reduced operation and maintenance cost.
- Restored or enhanced level of service.
- Risk exposure reduction. [Section 6.3.4]

Maintenance Processes

Within the term maintenance, there are two broad categories and a number of subcategories, as shown in Figure 12. This diagram excludes activities such as snow and ice control, cleaning, and incident response, which do not directly affect the physical condition of the asset. [Section 6.4]

Establishing a maintenance frequency helps to preserve the inherent levels of service of an asset, including reliability and safety, at minimum cost. At the early stage of asset management maturity, it can be difficult to establish these intervals reliably and to establish with certainty that they are the most cost-effective options. [Section 6.4.3]

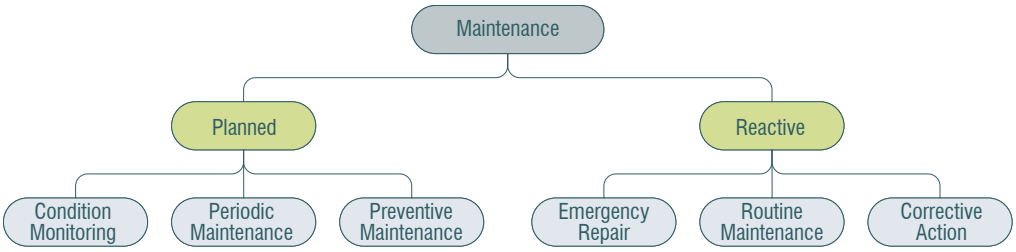

Figure 12. Maintenance Tasks

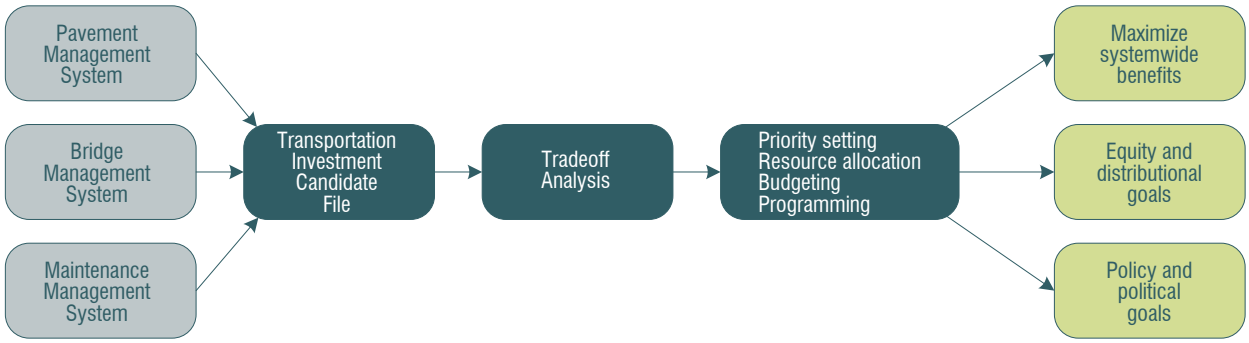

Figure 13. Road Map for Performance Information from Sources to Goals

Enabling Processes and Tools for TAM Integration

In its broadest sense, the goal of resource allocation in asset management is to deploy, maintain, and operate assets in a manner that maximizes accomplishment of the agency mission. Asset management attempts to quantify the degree of accomplishment of, in the expectation that what gets measured, gets done. Analytical functions of asset management are all geared toward measuring performance and forecasting how decisions might affect performance to maximize the agency's knowledge, control, and accountability over how well it fulfills its mission. Figure 13 shows the flows of performance information from their sources in agency management systems to their uses in setting and managing goals. [Section 7.1.1]

The types of analyses described in Chapter 6 and 7 of the *AASHTO Transportation Asset Management Guide—A Focus on Implementation* are not ends in themselves, rather they are the means to the end of providing the desired levels of service at the least cost to present and future customers. To achieve this, competing projects must be evaluated, prioritized, and have the necessary resources allocated to them. [Section 7.1.3]

Analytical Tools and Asset Management Decision Making

There are various analytical tools available that agencies can use in prioritization and decision making involving trade-offs. NCHRP Report 545 (2005) discusses the need for tools that cross the boundaries of asset type (e.g., pavement versus bridge), mode (e.g., highway versus transit), work class (e.g., maintenance, operations, or construction), or objective (e.g., safety, preservation, or mobility).

Figure 14, reproduced from NCHRP Report 545, illustrates a vision for how analytical tools could work with core asset information, agency business rules, and national or agency-specific parameters to provide improved decision-support capabilities. [Section 7.1.4.2]

The typical management cycle for implementing works on a highway network is shown in Figure 15. [Section 7.1.7.1]

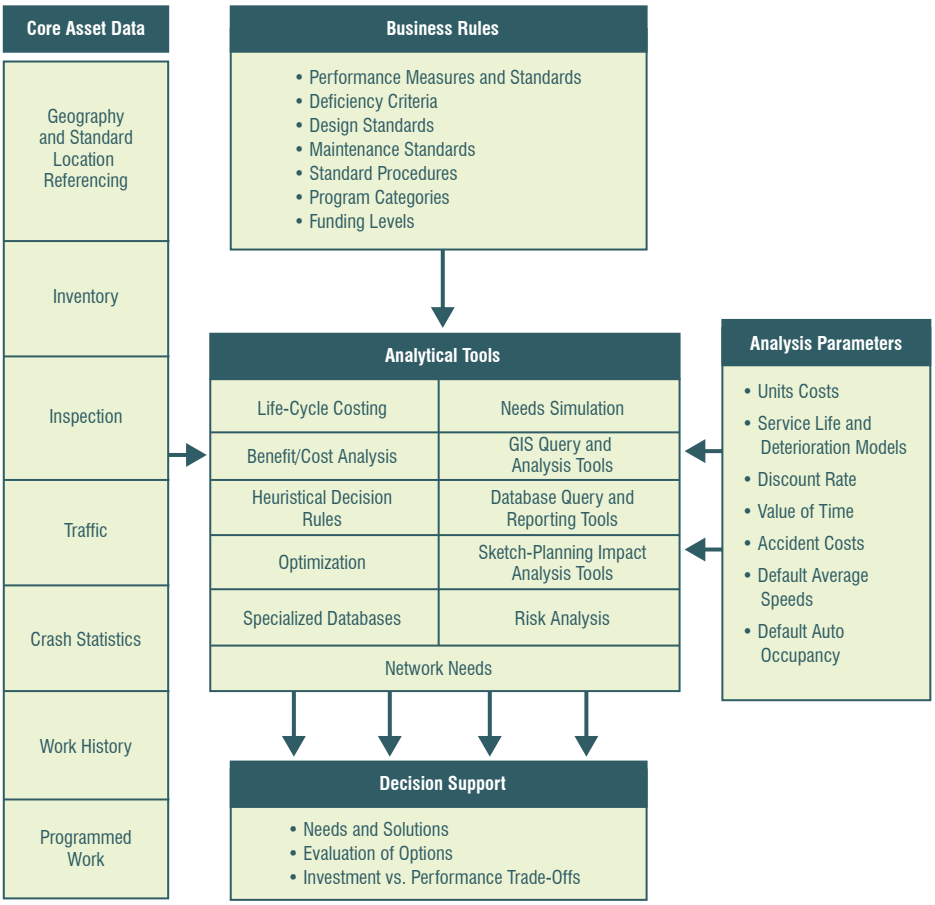

Figure 14. Context for Analytical Toolbox

Program Delivery

Program delivery is the process an agency takes to implement and deliver its plans and programs. It is the period where the resources that have been allocated are utilized. Key aspects of asset management during the program delivery phase are:

- Selecting a delivery method that yields the best results in terms of cost savings, output, and outcome.
- Maximizing efficiency during delivery so that cost is minimized.
- Maintaining flexibility to adjust delivery mechanisms if the chosen path is not yielding the desired results.
- Minimizing the negative impacts to customers and stakeholders during delivery.
- Monitoring to ensure that the goals and objectives driving the resource allocation decisions are being met. [Section 7.2]

Asset Valuation and Depreciation

Government agencies in the United States are required to report their financial performance annually, including their asset valuation. The details are contained in Government Accounting Standards Board Statement 34 (GASB 34). Future liabilities of the agency for the deterioration of its assets over time and through use must be understood, reported on, and provided for in its financial statements. [Section 7.3]

Depreciation is an expression of the consumption of the economic value of the asset though use. The value, capacity, or capability of the asset that is lost this way is restored though periodic replacement or reconstruction. If we do not adequately recognize the loss of service capacity of the assets that occurs through use, the concept of intergenerational equity that is the product of being "cost effective for present and future customers" becomes a difficult target. By gathering depreciation as the asset is used, and using these funds to replace the asset component at the end of its life, it is possible to match the costs of use and replacement, thus sharing these costs equitably between current and future customers.

In a transportation network that has been built and maintained over a long period, there is, in effect, a continuous requirement to replace asset components that have reached the ends of their useful lives. Comparing the cost of these renewals with the assessment of the value of the capacity lost through use (annual depreciation) can provide a useful indication of the sustainability of the management of the whole network. [Section 7.3.4]

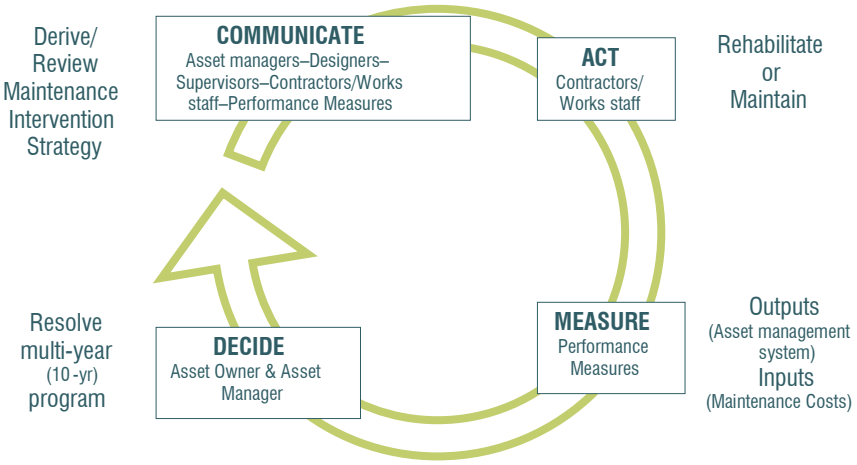

Figure 15. Typical Management Cycle (TNZ Manual)

Acting Sustainably

Transportation agencies have a significant role to play in providing highways and other infrastructure that enables communities to interact, to move goods and people, and to achieve economic growth. Transportation networks and systems represent a significant capital investment and they require ongoing expenditure and resources to continue to provide services. This section describes the different dimensions of sustainability pertaining to transportation agencies. [Section 7.4]

Economic sustainability represents a dynamic equilibrium where the economic activity of an agency attempting to improve performance is offset by forces that tend to degrade performance. These forces include deterioration, traffic growth, extreme events acting directly on the infrastructure, and external economic forces such as oil prices and global competition for materials and services.

A key sustainability issue for TAM is the ability to understand and quantify the relationship between resources consumed and expected outcomes; and with this knowledge to be able to select a set of performance levels that optimally balances resources and outcomes. [Section 7.4.3]

Social sustainability follows the same principles of intra-generational equity that have already been discussed from environmental and economic perspectives and thus requires the same broad awareness of repercussions of current action. [Section 7.4.4]

The parameters of the "service contract" provided by a transportation agency are the extent and quality of service, limitations on resources, and the positive and negative impacts of the economic activity itself (for example jobs,

economic stimulus, disruption, and work zone safety). External measures of performance are expressed in terms of transportation values as experienced by the public. They directly reflect public expectations of the transportation system. They describe the transportation system as a whole and not necessarily any specific part of it. [Section 7.4.5]

Integrating an awareness of sustainability issues into an agency's practice requires recognition of the overall performance of the transportation system and its interface with other systems including land use, economy, equity, and accessibility. It begins with an incorporation of sustainability goals into an agency's mission. Recognition of the impact on people, planet, and profit is included in the initial planning stage of projects and cascades throughout all activities and management of each asset's life.

As with other performance measures or objectives, sustainability must relate strategic goals to individual decision-points and procedures. It must include key performance metrics that ensure accountability and provide a mechanism for reporting back on actual implementation. Additionally, sustainability objectives and measures should be considered as part of any trade-off analysis. Key sustainability issues are the effects of the aging of transportation infrastructure resulting from deferred asset maintenance and deteriorating levels of service resulting from reduced network improvements. Limitations on funding to address these issues can, in turn, force transportation agencies to look for alternative ways to manage assets. Sustainable asset management is usually a better way of doing business. [Section 7.4.6]

Transportation Asset Management Information Systems

A Transportation Asset Management Information System (TAMIS) is a collection of hardware, software, data, and processes that support asset management business processes. A TAMIS is used to collect, process, store, and analyze information about assets; to develop sound maintenance and rehabilitation strategies; and to schedule, track, and manage work. TAMIS components and technologies are shown in Figure 16. [Section 8.1.1]

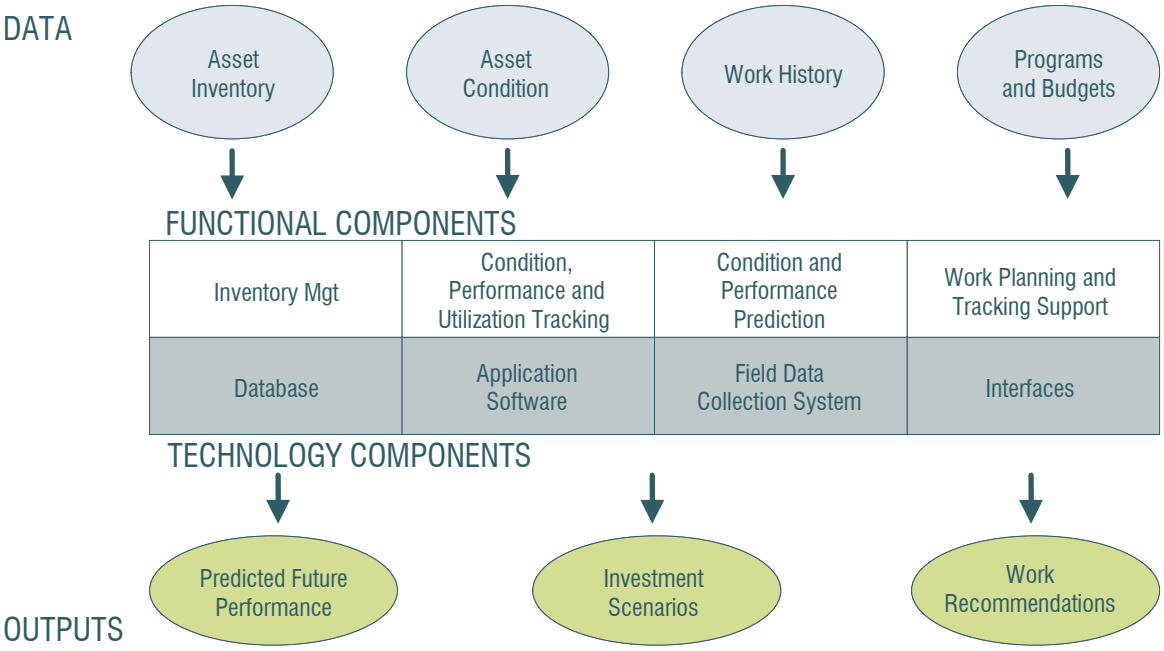

Figure 16. Data, Functional, and Technology Components of a TAMIS

Common functional elements of a TAMIS are:

- Asset inventory;
- Asset condition, performance, and utilization tracking;
- Asset condition and performance prediction;
- Treatment selection;

- Resource allocation; and
- Work planning and tracking support. [Section 8.1.2]

Information systems supporting asset management may be self-contained or have multiple interfaces to other agency data sets. An agency may have separate systems for each asset category, a single system with modules for multiple asset categories, or a mix. Systems may be commercial-off-the-shelf, "home grown," or a hybrid. Integration should be a major consideration in TAMIS design—lack of integration can mean duplication of data, manual processes to link data outside of the system or keep data in synch, and loss of potentially valuable decision support capabilities. [Section 8.2.1]

Key Principles for TAMIS Implementation

There is no single best approach to implementing a TAMIS. Each agency should evaluate current options on the market and develop an approach that best fits with their specific needs. Choices should be made with careful consideration of the agency's current application portfolio, technology environment, and staff resources. Continuous changes in information technology and commercial product offerings mean that what might have been the best choice 12 months ago may not be best today.

Implementation of advanced analytical capabilities and tight integration across systems can pay off but requires considerable commitment. Many agencies who implement sophisticated asset management systems do not make full use of their capabilities due to their own business needs, internal resource constraints, and the time, effort, and data required to build credible models that can be used for decision support. [Section 8.2.2]

Organizations undertaking implementation of new management systems or enhancement of existing systems should:

- Support decision-making and business processes. [Section 8.2.2.1]
- Develop an architectural vision. [Section 8.2.2.2]
- Designate a management sponsor and technical champion. [Section 8.2.2.3]
- Not underestimate resource requirements. [Section 8.2.2.4]
- Plan for incremental improvements. [Section 8.2.2.5]
- Ensure complete documentation. [Section 8.2.2.6]

Asset Management and Enterprise Resource Planning

Enterprise Resource Planning (ERP) initiatives streamline and centralize core business functions within organizations (or across organizations in a state or local jurisdiction), with a focus on financial and resource management. ERP efforts typically involve a combination of business process reengineering and information system consolidation and integration. Within a transportation agency, elements of an ERP system might include financial accounting, timesheets, payroll, materials management, fleet management, consumables inventory management, construction project scheduling and budgeting, grants management, federal aid billing, contract administration, and maintenance management. [Section 8.3]

ERP systems can support the work planning, scheduling, work tracking, and cost modeling functions of TAM. They can provide the platform for integration of information and workflow related to asset maintenance and rehabilitation activities and their associated resource requirements and costs. From the perspective of TAM, maximizing value from ERP systems requires design of account codes that allow for work and expenditure histories to be related to specific asset categories, locations, and objectives.

While ERP initiatives offer the potential to consolidate existing financial, maintenance, and project management information, it is generally agreed that successful implementations involve minimal customizations to out-of-the-box functionality. Therefore, some agencies find that specialized capabilities within their existing TAM systems cannot easily be replaced. For example, core TAM functionality such as snow and ice maintenance and other processes that involve beats (multiple, related linear assets) require customization to be incorporated into the ERP. [Section 8.3.1]

ERP offers the potential for agencies to realize substantial benefits, including reduction in paperwork, smoother and more integrated business processes, and reduced duplication of data—all of which can translate to greater efficiencies. In addition, ERPs can greatly improve access to valuable information for managers at all levels. Availability of timely information about the organization's assets, activities, expenditures, and resource utilization allows managers to make better decisions about how to utilize scarce resources for maximum payoff.

However, organizations embarking on ERP projects should be aware of the commitment required for realizing these benefits and the risks involved. ERP implementations can be costly, complex, and involve considerable organizational change. In order to achieve integration across business processes and information stores, units that have institutionalized and well-functioning work flow must change—and these changes can be disruptive.

Introducing change in multiple units across the organization is extremely challenging, even more so when the agency is under economic stress. Considerable up-front planning of an ERP implementation is required in order to avoid schedule slippage, cost overruns, and stress to the organization. [Section 8.3.3]

TAM Data Planning and Management

A TAM data planning and management function may be implemented as a cross-functional committee or may be housed within a single unit of the organization (e.g., within Information Technology, Planning, Maintenance, or Engineering units) with participation from the multiple units that produce and consume data relevant to TAM. The mission of the data planning and management function is to ensure that the right data are collected in an efficient manner to meet the organization's needs and that the data are managed throughout their life cycle to provide value. Ideally, TAM data planning and management will be integral to a general agency-wide data management program. Specific data planning and management practices are particularly relevant to TAM: data business planning, data governance, and data standards. [Section 8.4.2]

F. Additional Information

Gap Analysis Spreadsheet

The *AASHTO Transportation Asset Management Guide—A Focus on Implementation* Section 2.2.3 introduces the concept of TAM Gap analysis and provides an outline of a tool that can assist in determining these gaps. The Gap Analysis Spreadsheet facilitates gap analysis cross-referenced to the levels of TAM maturity discussed in Section 2.2.2. It allows the analyst to enter scores and produce charts comparing the agency's desired TAM performance with its current achievements. The tool is based on a series of individual questions, the answers to which are scored and aggregate upwards. It compares desired and achieved TAM performance across six assessment areas and across the categories that make up these assessment areas.

The tool can be downloaded from the AASHTO Subcommittee on Asset Management website, www.transportation.org/?siteid=95. [Section A.1]

The processes for using the tool are outlined in Figure 17, which also illustrates how the tool's outputs are taken through the TAM Improvement Plan.

Future Gap Analysis Tool

NCHRP 08-90, a study planned for 2013, is developing a TAM gap analysis tool that responds to the MAP-21 requirements and more closely matches the institutional and technical characteristics of U.S. transportation system management practices. The final tool will be spreadsheet-based as well as:

- Scalable in terms of programs and maturity levels.
- Customizable in terms of adding or deleting key assessment areas and individual questions.
- User friendly for practitioners with varying expertise.
- Readily accessible for different levels of analysis.
- Applicable by functional area (e.g., policy guidance, planning and programming, etc.).
- Accompanied by metadata.
- Structured and programmed for agency wide use.
- Tested with a sample of state DOT practitioners for practical usability.
- Accompanied by reporting functions that include appropriate visual and text outputs that could be used as inputs by practitioners and decision makers for identifying prioritized areas of improvement to address gaps and develop a TAM Improvement plan.

The final tool will be incorporated into the *AASHTO Transportation Asset Management Guide—A Focus on Implementation.*

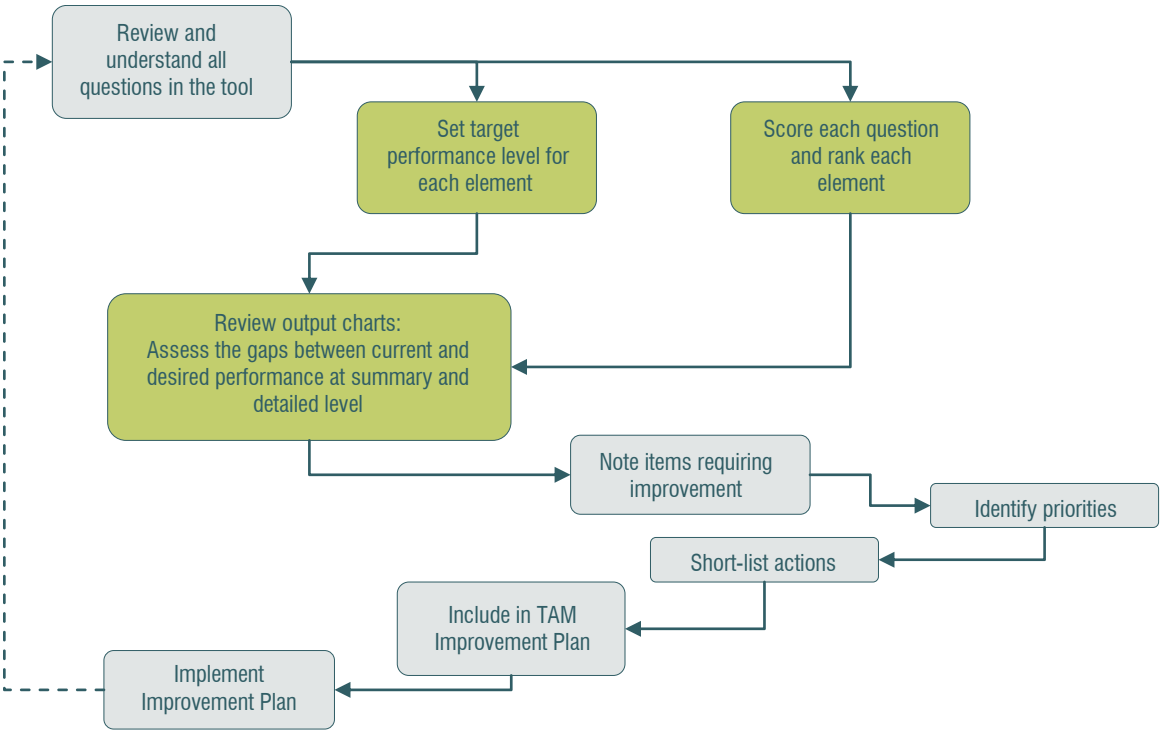

Figure 17. Gap Analysis Process

Case Studies

Colorado

The Colorado Department of Transportation (CDOT) is responsible for the state's transportation system including roadways, rail corridors, transit services, bicycle and pedestrian ways, and commercial and general aviation. Like many DOTs, CDOT is balancing an aged system in need of extensive repair (nearly 70 percent of the interstate system was built before 1970); environmental and geographic challenges, including high elevations and harsh winters; system wear from more than 23 billion vehicle miles of travel annually; and the increasing and sometimes conflicting pressures involved in moving passengers, freight, and information on an interregional and interstate level while meeting the needs of urban and rural residents. Funding shortfalls have increased the difficulties of meeting all of the state's transportation needs.

In response to these challenges, CDOT has been on a continuous improvement asset management journey since the early 1990s. The agency has one of the nation's most mature pavement management systems, was an early adopter of the Pontis bridge management system, and initiated one of the first maintenance management levels of service approaches. These initiatives were driven by a focus on good investment planning that began almost 20 years ago and continues into the present with the recent implementation of the SAP ERP system that supports the department's asset management program.

The highway system comprises 9,161 centerline miles of roadway, more than 3,700 bridges, and 20 state-owned tunnels over 104,100 square miles. The agency employs 3,300 staff, of which approximately 1,900 work in maintenance. It supplements employees with limited use of consulting engineers.

Colorado's highway system is funded primarily through the Highway Users Trust Fund (HUTF) and Federal HTF, supplemented in a strong economy by state general funds using a prescribed formula. This approach leads to highly variable funding levels. For example, the 2008 economic downturn resulted in a funding drop from $1.5 billion in FY 2008 to ≈$1 billion in FY 2009. [Section B.1]

CDOT's commitment to asset management started in the 1990s when the agency began defining investment categories, associated performance measures, and relevant data. These investment categories are:

- **Safety**—Services, programs, and projects that reduce fatalities, injuries, and property damage for all users and providers of the system.
- **System Quality**—Activities, programs, and projects that maintain the physical (integrity/condition) function and aesthetics of the existing transportation infrastructure.
- **Mobility**—Programs, services, and projects that enhance the movement of people, goods, and information.
- **Program Delivery**—Functions that enable the successful delivery of CDOT's programs, projects, and services.

These investment categories allowed the agency to develop an asset management framework that relates investments to policy objectives and impacts rather than funding sources. This approach enhanced management's ability to analyze trade-offs among programs and paved the way to future TAM initiatives that included an updated planning and prioritization process, integration of levels of service, customer surveys, and guidance for updating technology infrastructure.

Late in the 1990s, the agency fully committed to asset management and, since then, has devoted significant resources to a continuous improvement effort that builds on the success of previous initiatives. They formed an Asset Management Task Force, which was headed by CDOT's deputy director and included 10 representatives from across the department. The group was responsible for overseeing the implementation of an asset management plan, including providing high-level leadership and communicating plans and accomplishments to the Transportation Commission.

During the same time period, the agency implemented stand-alone management systems for pavements, bridges, and maintenance.

In the early 2000s, senior management insisted all new technology purchases and implementation be reviewed by a policy group that evaluated whether the proposed systems were commensurate with a vision of enterprise asset management practices. This group also became responsible for recommendations regarding business processes and technology practices that would support the asset management program.

In addition, an asset management steering committee was formed to guide the implementation of management systems and gain support inside the agency. A third leadership group, an executive management subcommittee, evaluates the strengths and weaknesses of CDOT's performance measures and compares them to best practices. Unity of vision and strategies is accomplished by having members serve on more than one asset management leadership team.

In 2004, the agency committed to development of an ERP for financial management and to integrate data from different systems in a way that would serve the needs of the entire institution and help maximize the value of investment choices. An Enterprise Resource Planning Steering Committee, consisting of high-level management, was appointed to guide the ERP implementation.

CDOT's current asset management program integrates a mature investment/budgeting process, strong management systems, one of the country's first implementations of performance-based budgeting, and an integrated ERP system. The agency will continue to build the capabilities of the ERP to further enhance its usefulness. [Section B.3]

Missouri

Defining clear policy and performance goals, monitoring progress toward those goals, and communicating with external stakeholders and decision makers as well as employees of the agency are all key aspects of effective asset management. Performance measures, and the application of performance measures through performance management, are important tools in carrying out these parts of asset management. The Missouri Department of Transportation (MoDOT) is responsible for the seventh largest state highway system in the country. [Section C.1]

The agency's performance is published regularly both on paper and on the web in a document known as Tracker. To manage this measurement system and to make it meaningful to the agency, each tangible result is assigned a driver. The result driver is a senior manager (the agency director, chief engineer, chief financial officer, or a division

director). This result driver has overall responsibility for the performance of the result area across the organization. Fulfilling this obligation requires a combination of information sharing and advocacy to encourage performance on results that cut across the agency. Each tangible result is defined by at least three specific measures. Several have a dozen or more measures. In total, MoDOT tracks about 120 specific measures. Each measure is also assigned a driver. These measurement drivers are typically middle managers with hands-on responsibility for the area being measured and the data being reported.

Each quarter, the drivers meet with all senior management, typically more than 75 people, to review the progress toward each tangible result and each measure. The agency head presides at these meetings, where result drivers are challenged to outline the steps they have taken to ensure that the measures indicate progress toward the right result. Actions that are planned for the future are not acceptable responses to a tangible result that is falling behind expectations. Managers are expected to have already taken steps to correct unacceptable trends.

The quarterly review meetings are also the forum in which changes can be made to measures. If the measure does not seem to be providing the information desired, the drivers may be asked to find new or modified measures that will provide more or better information on the tangible result. When changes are made, they are noted in the Tracker report with their impact documented.

Managers are encouraged to link the annual performance objectives of individual employees to specific measures and tangible results. MoDOT management philosophy discourages defining specific performance targets. [Section C.2]

New Zealand

The New Zealand Transport Agency (NZTA) is a Crown Entity established by statute in August 2008. Its establishment merged the functions of Land Transport New Zealand (LTNZ) and Transit New Zealand (Transit).

NZTA is responsible for the New Zealand national state highway system. It is also responsible for managing Crown revenue of $NZ 2.8 billion and the allocation of $NZ 2.0 billion annually to the land transport system and has an operating budget of approximately $NZ 240 million. Governance is provided by a Chairman and Board whose members are regularly appointed by the government. NZTA currently employs 1,300 staff across eleven offices and six regions. The organization is managed centrally.

Since 1989, there have been various institutional changes in the sector. Prior to 2008, LTNZ had been responsible for allocating funds to road-controlling authorities throughout the country, as well as operational issues such as road safety. LTNZ had itself been formed from an earlier merger of the Land Transport Safety Authority (a safety focused agency) and Transfund New Zealand (the funding agency). The original Transit organization also held the funding responsibilities of Transfund, but these were devolved early in its life. Interestingly, they have now been returned to the new NZTA.

Prior to 1989, state highways had been managed by a government department, the Ministry of Works and Development. This organization was also responsible for other government owned assets, and it employed its own work force for professional services and construction forces. Transit was formed in 1989 by statute, with one of the most significant changes being a requirement to outsource many services to the private sector. [Section D.1.1]

Key laws include the Transit New Zealand Act, the Land Transport Management Act, and various amendments. Legislation has dictated the institutional changes and the move from in-house delivery of all services to an outsourcing model, a change which has had far-reaching implications for TAM development. [Section D.2.2]

While legislation played a significant role in the change process, the early devolution of the former government department-based structure to a much smaller organization which outsourced service delivery to the private sector provided a challenge and an impetus for a changed way of thinking and a changed way of working. The new organization needed to become a “smart buyer” of professional engineering services and maintenance and construction contracts. This required strong vision-led leadership. [Section D.2.3]

For this to succeed, role clarity and involvement at all levels within the organization and the supply chain was needed—including training providers, software development, consultants, and contractors. There were many different roles which played out as implementation progressed. Existing organizational management systems now include formalized staff accountabilities related to TAM, such as achieving level of service or performance targets for particular aspects of the network. [Section D.2.4]

Transit also recognized the importance of creating and cultivating a "community of interest" for TAM within the roads transportation sector in New Zealand. [Section D.2.5]

The reorganization of the late 1980s was a catalyst for change, and with that change came a focus on quality asset data. This has been a key both to TAM and to how work is procured. While the journey began with data, it now fully encompasses management systems and analysis. [Section D.3]

Wyoming

The Wyoming Department of Transportation (WYDOT) serves the ninth largest state in the country by providing construction and maintenance services, law enforcement, and administrative and regulatory services for Wyoming's transportation system. In addition to the highways, the agency is responsible for the state's aviation and rail programs and embraces goals for non-motorized transportation (bicycling and walking).

WYDOT recognized the importance of people, process, and technology in the establishment of their asset management program. A key component of the WYDOT's asset management journey involved the procurement of an Enterprise Resource Planning System (ERP) from PeopleSoft along with the implementation of asset management systems (AgileAssets). The current focus of their TAM implementation is the use of information to reach better decisions. Another noteworthy aspect of WYDOT's experience is the integration of the Balanced Scorecard as their performance management framework. [Section E.1]

Wyoming's focus on asset management has been relatively recent. It evolved in response to the state's transportation needs outstripping their funding to such an extent that a "worst first" approach to budgeting was not going to support them in reaching their goals. The state has a significant gap between roadway needs and funding. Pavement condition has been deteriorating over the past decade and is projected to continue declining if funding continues at the current rate. State expenditure for capital construction and maintenance in 2007 was approximately $391 million.

In an effort to address this situation, the state sought to increase funding levels through a proposal to raise Motor Fuel Tax (MFT) rates. The proposal was rejected in both the 2007 and 2008 legislative sessions. In 2008, the state legislature provided an additional $200 million in general funds for highways. However, only half of this amount went into the DOT's budget; the rest could only be accessed following legislative appropriation in response to an agency request.

Given the funding shortfall and asset needs and the need to acquire new financial management software, WYDOT recognized the opportunity to approach budgeting in a new way and began building the components of an asset management program. A significant part of this effort has been the implementation of an ERP system to integrate financial data. [Section E.1.3]

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