CHAPTER 3

Self-Assessment and Improvement Identification

This chapter provides detailed supporting materials for assessment and improvement identification. This content is organized around the five areas of the data life-cycle.

Agencies are encouraged to limit the scope of the assessment to a single asset class or to 1 to 2 data life-cycle areas for multiple assets. This approach will ensure that the process doesn't pose an undue burden on participants while providing a substantive look at a specific area of interest.

Self-Assessment Framework and Materials Overview

This section details the technical framework used to organize the assessment and improvement identification materials, and provides area- and section-specific materials to support the assessment process. The technical framework is developed around the data life-cycle, which, for the purposes of this guidance has been broken down into five (5) areas. Each area is further organized into sections containing a variety of individual elements.

Area A: Specify and Standardize Data

This area supports the understanding of the needs and full costs of asset inventory, condition and performance, treatment, and work history data. This area also addresses the documentation of data meaning, derivation, and quality, and the establishment of governance structures and processes and associated stewardship roles and responsibilities. Area A is subdivided into five sections that together comprise fifteen individual elements. The sections and elements are:

- A.1: Inventory, Condition, and Performance Data Standards
  - A.1.a: Asset Inventory Data Model
  - A.1.b: Asset Condition and/or Performance Data Model
  - A.1.c: Design Model Standards
  - A.1.d: Location Referencing
- A.2: Treatments and Work Data Standards
  - A.2.a: Treatments and Work Data Model
  - A.2.b: Treatments and Work Location Referencing
  - A.2.c: Process Documentation and Management
- A.3: Resource Allocation and Prioritization Standards
  - A.3.a: Prioritization Factors
  - A.3.b: Analysis Parameters
- A.4: Metadata Standards
  - A.4.a: Data Dictionary Standards and Guidelines
  - A.4.b: Dataset Metadata Standards and Guidelines

- A.5: Governance Standards
  - A.5.a: Data Stewardship
  - A.5.b: Data Standards and Guidelines Development/Adoption Processes
  - A.5.c: Data Collection Approval/Coordination Processes
  - A.5.d: Change Control (Systems and Data) Processes

Area B: Collect Data

This area explores TAM-related data collection processes and practices, tools and technologies, and quality as delivered with respect to existing data standards. Area B is subdivided into four sections that together comprise eleven individual elements. The sections and elements are:

- B.1: Inventory, Condition, and Performance Collection
  - B.1.a: Inventory, Condition, and Performance Coverage
  - B.1.b: Inventory, Condition, and Performance Automation
  - B.1.c: Inventory, Condition, and Performance Quality
- B.2: Project Information Collection;
  - B.2.a: Project Information Coverage
  - B.2.b: Project Information Automation
  - B.2.c: Project Information Quality
- B.3: Maintenance Information Collection
  - B.3.a: Maintenance Information Coverage
  - B.3.b: Maintenance Information Automation
  - B.3.c: Maintenance Information Quality
- B.4: Priority Criteria and Values Collection
  - B.4.a: Public Perceptions
  - B.4.b: Decision-Maker Values

Area C: Store, Integrate, and Access Data

This area addresses data availability across the enterprise and the elimination of redundant and duplicative data. Specific asset life-cycle process areas, as well as external data and process areas, are identified for data standardization and integration to streamline business processes and improve decision-making. Area C is subdivided into four sections that together comprise fourteen individual elements. The sections and elements are:

- C.1: Databases
  - C.1.a: Efficient Storage
  - C.1.b: Database Linkages
  - C.1.c: Document Linkages
  - C.1.d: Data Storage Capacity
- C.2: Asset Life-Cycle Data Integration Workflows
  - C.2.a: Asset Management Data to Project or Work Order
  - C.2.b: Project Planning to Project Development
  - C.2.c: Project Development to Project Delivery
  - C.2.d: Project Delivery to Asset Management Data
- C.3: Other Data Integration Workflows
  - C.3.a: Financial (Revenue, Budget, and Expenditure) Data
  - C.3.b: Demand and/or Utilization Data
  - C.3.c: Environmental Data

- C.4: Data Access
  - C.4.a: Field Access to Data
  - C.4.b: Public Access to Data
  - C.4.c: Access Security

Area D: Analyze Data

This area examines decision-support tools, techniques, and practices that facilitate the development of actionable information and insights to support decision-making. Area D is subdivided into two sections that together comprise five individual elements. The sections and elements are:

- D.1: Data Exploration, Reporting, and Visualization
  - D.1.a: Analysis Environment
  - D.1.b: Analysis Practices
  - D.1.c: Analysis Tools
- D.2: Modeling
  - D.2.a: Asset Performance Prediction
  - D.2.b: Optimization/Prioritization

Area E: Act as Informed by Data

This area covers data-informed TAM practices, exploring asset life-cycle management through resource allocation and prioritization; project planning, scoping, and design; and maintenance decision-making. Area E is subdivided into three sections that together comprise six individual elements. The sections and elements are:

- E.1: Resource Allocation and Prioritization
  - E.1.a: Performance Targeting
  - E.1.b: Project Prioritization
- E.2: Project Planning, Scoping, and Design
  - E.2.a: Data-Driven Project Planning and Scoping
  - E.2.b: Data-Driven Project Design
- E.3: Maintenance
  - E.3.a: Infrastructure Maintenance
  - E.3.b: Equipment Maintenance

Detailed Data Life-Cycle Framework

Figure I-3 provides a representation of the complete data life-cycle framework, comprising five areas, 18 sections, and 51 elements.

The balance of this chapter shares supporting guidance and context for each area and section within this framework and is designed to supplement and support detailed element-level practice benchmarks and potential improvement recommendations.

Assessment and Improvement Identification

The TAM Data Assistant includes descriptions of each assessment element, practice benchmarks, and associated improvements. In this report, reproducible versions of these descriptions are included as Element-Level Response Templates in Part III, Appendices A through E.

A. Specify and Standardize		
A.1 Inventory, Condition, and Performance Standards	A.1.a	Asset Inventory Data Model
	A.1.b	Asset Condition and/or Performance Data Model
	A.1.c	Design Model Standards
	A.1.d	Location Referencing
A.2 Treatments and Work Standards	A.2.a	Treatment and Work Data Model
	A.2.b	Treatment and Work Location Referencing
	A.2.c	Process Documentation and Management
A.3 Resource Allocation and Prioritization	A.3.a	Prioritization Factors
	A.3.b	Analysis Parameters
A.4 Metadata	A.4.a	Data Dictionary Standards and Guidelines
	A.4.b	Dataset Metadata Standards and Guidelines
A.5 Governance	A.5.a	Data Stewardship
	A.5.b	Data Standards and Guidelines Development/Adoption Processes
	A.5.c	Data Collection Approval/ Coordination Processes
	A.5.d	Change Control (Systems and Data) Processes

B. Collect		
B.1 Inventory, Condition, and Performance Collection	B.1.a	Inventory, Condition, and Performance Coverage
	B.1.b	Inventory, Condition, and Performance Automation
	B.1.c	Inventory, Condition, and Performance Quality
B.2 Project Information Collection	B.2.a	Project Information Coverage
	B.2.b	Project Information Automation
	B.2.c	Project Information Quality
B.3 Maintenance Information Collection	B.3.a	Maintenance Information Coverage
	B.3.b	Maintenance Information Automation
	B.3.c	Maintenance Information Quality
B.4 Priority Criteria and Values Collection	B.4.a	Public Perceptions
	B.4.b	Decision Maker Values

C. Store, Integrate, and Access		
C.1 Databases	C.1.a	Efficient Storage
	C.1.b	Database Linkages
	C.1.c	Document Linkages
	C.1.d	Data Storage Capacity
C.2 Asset Life-Cycle Data Integration Workflows	C.2.a	Asset Management Data to Project or Work Order
	C.2.b	Project Planning to Project Development
	C.2.c	Project Development to Project Delivery
	C.2.d	Project Delivery to Asset Management Data
C.3 Other Data Integration Workflows	C.3.a	Financial (Revenue, Budget, and Expenditure) Data
	C.3.b	Demand and/or Utilization Data
	C.3.c	Environmental Data
C.4 Data Access	C.4.a	Field Access to Data
	C.4.b	Public Access to Data
	C.4.c	Access Security

D. Analyze		
D.1 Data Exploration, Reporting, and Visualization	D.1.a	Analysis Environment
	D.1.b	Analysis Practices
	D.1.c	Analysis Tools
D.2 Modeling	D.2.a	Asset Performance Prediction
	D.2.b	Optimization/Prioritization

E. Act		
E.1 Resource Allocation and Prioritization	E.1.a	Performance Targeting
	E.1.b	Project Prioritization
E.2 Project Planning, Scoping, and Design	E.2.a	Data-Driven Project Planning and Scoping
	E.2.b	Data-Driven Project Design
E.3 Maintenance	E.3.a	Infrastructure Maintenance
	E.3.b	Equipment Maintenance

Figure I-3. The complete data life-cycle framework.

Assessment participants can use the templates to become familiar with the material before using the tool in a group setting.

Before completing an assessment, participants are encouraged to review the area- and section-specific guidance materials that follow. These materials provide context and examples that will help participants understand the benchmark levels and their associated improvements.

Agency staff can evaluate the current and desired state of agency practice against element-level practice benchmarks and select from potential improvements to close identified gaps.

Completing the Assessment

The following steps are recommended to complete the assessment:

1. **Review the element-level response templates** in appendices A through E to become familiar with the material. For any given assessment, it is only necessary to look at those areas/sections that have been selected as relevant to that assessment.
2. **Read the guidance material in this chapter for the selected areas/sections.** This material helps define the scope of each portion of the assessment.
3. **Work through the assessment** before meeting as a team, either by using the templates in appendices A through E, or by using the TAM Data Assistant. This step will allow all members of the team to think through the material in advance.
4. **Share the results of Step 3 at group assessment sessions** and work toward a set of consensus results that characterize the agency's current and desired practices in relation to benchmark levels and the improvements to be considered.

Understanding Benchmark Levels

For each assessment element, the individuals completing the assessment will select two benchmark levels (ranging from 0 to 4) to represent agency's practice levels related to that element. The first benchmark level selected represents the agency's *current* level of practice, and the second represents the agency's *targeted* level of practice.

General practice-level descriptions for each benchmark level are provided in the text box titled "Benchmark Levels." For each assessment element, a more tailored set of benchmark levels has been provided in Part III, Appendices A through E.

Benchmark Levels

General Practice-Level Descriptions

0 **Non-Existent:** The DOT does not have any significant practices within this aspect of their business.

1 **Initial Steps:** DOT practices are found; however, these are characterized by ad hoc or informal application, and they are not likely to be endorsed by management.

2 **Incremental Improvement:** The DOT is beginning to see formalization of the processes and structures within this aspect of their business.

3 **Advanced Practice:** The DOT is performing at a level at or above the standard of their peers.

4 **Top Performing:** The DOT is a leading example of practice among their peers.

Selecting Target Levels

Assessment teams should not assume that the target benchmark level should be selected at the highest possible level (4) for all of the assessment elements. An agency may currently be at Benchmark Level 0 for a particular element because there is no particular benefit to advancing in that area. For example, it may not be cost-effective to collect data or perform sophisticated analysis for an asset that has a very short life-cycle and accounts for a small portion of the agency's budget.

The benchmark levels have been defined in a way that assumes the agency must pass through each level to get to the next level. In other words, it isn't possible to skip levels. This means that, to advance, the most reasonable target for any specific element will often be the next benchmark level up from where the agency currently is.

It is helpful to use a standard timeframe (e.g., 2–3 years) when setting target levels. The target level should be (1) beneficial for the agency to reach and (2) realistic to achieve within the target timeframe.

Selecting Candidate Improvements

In this guidebook, candidate improvements are suggested for each benchmark level. These improvements are designed to move an agency up from its current level to the next level. Keep in mind that not all candidate improvements will be appropriate for every agency. Agencies should feel free to tailor them to their specific situation—or create new candidate improvements that would help the agency advance from its current level to the next level.

Area and Section Guidance

The next sections of this chapter provide guidance for each assessment area and section. Transportation agencies can use this guidance to:

- Understand the definition and scope of each assessment area and section;
- Understand some of the issues and key decisions to be made when considering improvements related to each section; and
- Review conceptual examples of agency practice relevant to the section.

Response Templates

Appendices A through E provide paper-based response templates that can be used to complete self-assessment and improvement identification independently of the digital TAM Data Assistant. A paper-based approach is not recommended for full application of the guidebook; however, it can be useful for individual preparation in advance of group self-assessment discussions.

Response Templates

Area A: Specify and Standardize Data
Appendix A

Area B: Collect Data
Appendix B

Area C: Store, Integrate, and Access Data
Appendix C

Area D: Analyze Data
Appendix D

Area E: Act as Informed by Data
Appendix E

Area A: Specify and Standardize Data

This area deals with establishing asset, treatment, and work data standards, standard prioritization factors, metadata standards, and comprehensive governance programs.

Area A: Specify and Standardize Data

- A.1: Inventory, Condition, and Performance Data Standards
- A.2: Treatments and Work Data Standards
- A.3: Resource Allocation and Prioritization Standards
- A.4: Metadata Standards
- A.5: Governance Standards

Area Overview

Area A is organized into five distinct sections:

- **A.1: Inventory, Condition, and Performance Data Standards,** covering asset inventory, condition, and performance data models, as well as supporting design and location referencing standards;

- **A.2: Treatments and Work Data Standards,** covering asset treatment and work data models, as well as the supporting design and location referencing standards;
- **A.3: Resource Allocation and Prioritization Standards,** covering definition of standardized prioritization factors and analysis parameters;
- **A.4: Metadata Standards,** covering dataset-level and data element (data dictionary) metadata standards and guidelines; and
- **A.5: Governance Standards,** covering roles, responsibilities, and processes for adoption of data standards and guidelines, data change control, and data collection approval and coordination practices.

Improvements in this area aim at specifying data requirements to align with agency business needs, standardizing data models so that information from different systems can be integrated and aggregated for analysis and reporting, and formalizing roles and processes to ensure alignment and coordination across different stakeholders.

Area A: Specify and Standardize Data

A.1: Inventory, Condition, and Performance Data Standards

A.2: Treatments and Work Data Standards

A.3: Resource Allocation and Prioritization Standards

A.4: Metadata Standards

A.5: Governance Standards

Section A.1: Inventory, Condition, and Performance Data Standards

Credible, reliable data begins with well-defined and understood standards. Inventory, condition, and performance data are the most important components of a data-informed TAM program. Location referencing and design standards also are essential to support integration across life-cycle systems and with other data (such as roadway use or environmental data).

Required, Recommended, and Optional Data Attributes

Agencies can establish clear data requirements by documenting comprehensive inventory, condition, and performance data models. Gather input from key stakeholders to ensure models meet business needs and are practical to collect and maintain.

Clearly identify required, recommended, and optional data attributes (see **Figure I-4**). Required and recommend fields should be feasible to collect and maintain; optional fields may only be collected under specific circumstances. Data that cannot be reliably collected or maintained should be excluded from the data model.

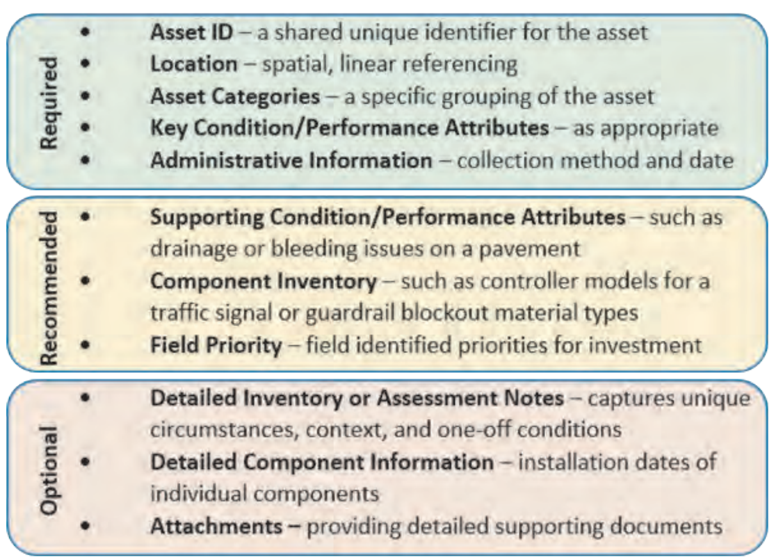


Figure I-4. Examples of required, recommended, and optional inventory, condition, and performance data attributes.

Minimum Data Coverage

Agencies can examine asset and performance management decision-making needs to establish clear requirements for where, when, and how often asset inventory, condition, and/or performance data will be collected (see text box for conceptual examples).

Conceptual Examples

Targeted Data Coverage Based on Asset Life-Cycle Considerations

Streamlining Pavement Marking Performance Data Collection

Certain pavement marking materials have a service life of less than 1 year. An annual retro-reflectivity performance data collection adds little value where these markings are used; therefore, these can be excluded from collection.

Network-Level Data Collection Requirements

Focusing Network-Level Collection

Maintaining network-level data collection to meet detailed project-level design requirements is not generally cost-effective—data do not stay accurate, due to changing field conditions as well as maintenance and project work. Focus statewide collection on meeting requirements for network-level use cases (e.g., performance management, needs analysis, investment prioritization).

In some cases, a complete network-wide collection may not be needed or may not be practical given resource constraints. In these situations, collection can be limited to what can be collected and maintained in a timely, cost-effective manner—and targeted to what is most valuable to decision-makers.

Important Terminology

The following terms are used within this section:

- **Data attribute,** meaning a specific piece of the data model, describing a data entity. A data attribute contains a specific fact important to the business (e.g., Bridge ID, Sign Type, Pavement Roughness, or Install Date).
- **Asset breakdown structure,** meaning a hierarchical model of the agency's assets, with high-level categories (e.g., *traffic assets*) and subcategories (e.g., *traffic signals*).
- **Location referencing system,** meaning a set of data and procedures for managing locations of geographic objects using one or more methods for specifying a location. For TAM, a location referencing system often includes a linear referencing system that specifies location as the distance along the roadway from a reference point (e.g., a county boundary or intersection).
- **Component breakdown,** involving models that divide complex assets into individual parts of the larger whole, such as dividing a bridge into the deck, superstructure, and substructure.
- **Asset information model,** as defined by Building Information Modeling (BIM) standards (ISO 19650), meaning a model that compiles the data and information related to or required for the operation of an asset.

Associated Response Templates

A.1.a: Asset Inventory Data Model

A.1.b: Asset Condition and/or Performance Data Model

A.1.c: Design Model Standards

A.1.d: Location Referencing

Appendix A

Area A: Specify and Standardize Data

A.1: Inventory, Condition, and Performance Data Standards

A.2: Treatments and Work Data Standards

A.3: Resource Allocation and Prioritization Standards

A.4: Metadata Standards

A.5: Governance Standards

Section A.2: Treatments and Work Data Standards

Standardized data on asset treatments and work allows agencies to coordinate improvement planning across funding programs, understand asset maintenance and rehabilitation costs, compile a unified work history for an asset, and build meaningful models of the performance of different treatments.

Required, Recommended, and Optional Data Elements

Required and recommended fields should be feasible to collect and maintain; optional fields may be collected only under specific circumstances; and data that cannot be reliably collected or maintained should be excluded from the data model elements (see **Figure I-5**).

Minimum Data Coverage

Agency staff examines the DOT's asset management decision-making needs to establish clear requirements for what extent treatment or work history data attributes will be collected (e.g., Interstate work history may be required, whereas other work may not be captured).

It is important to balance the cost of tracking treatment information against the value the data will add to decision-making. For example, it may be costly to record itemized, location-specific information about certain minor or routine maintenance activities, particularly if the needed information can be collected and tracked in a more aggregated manner.

Location-Based, Asset-Based, and Other Work Tracking Mechanisms

Asset treatment and work can be captured by work location (e.g., paving on a particular route between specific mile points) or against the asset inventory (e.g., rehabilitation of a specific bridge). In some cases, geographic or organizational-level (e.g., county-wide summary) or contract or project-level information is sufficient. For each work type, consider and incorporate the necessary level of granularity for tracking into the data model and collection requirements (see text box for conceptual examples).

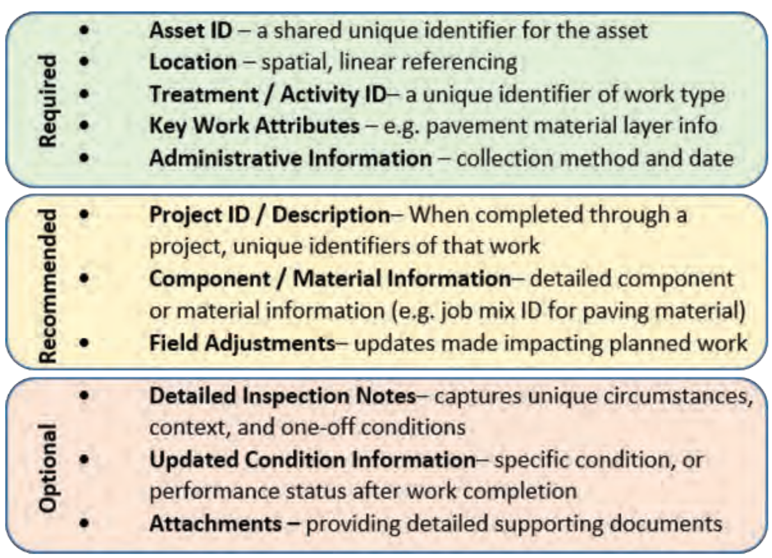


Figure I-5. Examples of required, recommended, and optional treatment and work data.

Conceptual Examples

Targeted Data Collection for Minor/Routine Work

Streamlined Guardrail Damage Repair Treatment Data Collection

When spot repairs to the guardrail rail sections do not impact the overall guardrail system length, configuration, product type, or functional condition, detailed work or project information may not be necessary for asset management purposes. This decision can be reflected in the data model and requirements.

Confirmation of As-Built Data

Pavement Maintenance Treatment History

Planned paving activities may be subject to field adjustments (e.g., project limits may be shortened or extended, paving sections added or removed, or treatment material types or thickness may be modified based on prevailing field conditions or available funding). For certain activities, it may only be necessary to reflect adjustments to the work location (e.g., when patching, for which treatment details are unlikely to change). For other activities, however, detailed treatment information may need to be captured in the field to ensure accuracy of critical information such as material types and thicknesses. Agency staff need to consider these circumstances when establishing detailed field data collection data models and requirements.

Important Terminology

The following terms are used within this section:

- **Work accomplishments,** meaning the type and quantity of completed work on assets (e.g., inspections, repairs, or replacements). Descriptions of work accomplishments may include other information, such as date completed, whether the work was performed by state forces or contract, resources used, and cost.
- **Data exchange protocol,** meaning the standard rules for data transfer between project design, delivery, and asset life-cycle management systems and/or process participants.
- **Project information model,** as defined by the ISO 19650 standard, meaning a model developed during project design and construction that begins as a design intent model, and then evolves to be a virtual construction model.

Section A.3: Resource Allocation and Prioritization Standards

Standardized prioritization factors and analysis parameters are critical to support high-level asset management decision-making and resource allocation.

When standardized across the agency asset portfolio, these factors and parameters support alignment of investments with the agency's mission, goals, and objectives, and support transparency in decision-making.

Associated Response Templates

A.2.a: Treatments and Work Data Model

A.2.b: Treatments and Work Location Referencing

A.2.c: Design Model Standards

Appendix A

Alignment with Planning

TAM resource allocation prioritization factors and analysis parameters should reflect the organizational goals, objectives, and priorities established in the agency's long-range transportation plans, state transportation improvement plans, TAM plans, and other similar or related documents. Through alignment with planning, TAM resource allocation can effectively communicate program value, priorities, and needs to better compete for limited agency funds.

Typical Prioritization Factors

An agency might prioritize asset or investment decisions in any number of ways. Conceptual examples of prioritization factors are shared in the text box.

Conceptual Examples

TAM Investment Prioritization Factors

Asset Tiers

Agencies may group assets into management tiers to support cross-asset prioritization. For example, Bridge, Pavement, and ITS assets may be prioritized over other assets.

Roadway Classification

Agencies commonly prioritize maintenance or replacement of assets on Interstate or higher functional class roadways over roadways with lower classifications.

Asset Classification

It is helpful to examine asset sub-types or classifications to identify investment priorities. For example, 4-bolt cantilever structures may be prioritized for maintenance or inspection over other types of structures due to safety concerns.

Asset Condition, Performance, or Known Deficiencies

Investment in assets may be prioritized within certain condition or performance levels. For example, traffic signals that are operating inefficiently may be prioritized for retiming, component repair, or replacement, or even for a full rebuild.

Asset Usage or Risk-Based Factors

High-use or high-risk assets are often a prioritized TAM investment. Examples include bridges with long detour lengths and the use of roadway departure crash rates to prioritize roadside safety hardware investment.

Analysis Parameters

The following are typical analysis parameters:

- **Analysis horizon,** which establishes the base and future years for the analysis.
- **Network or inventory,** which identifies the included/excluded subsets of the asset inventory or agency network.
- **Available funding,** which documents current and/or projected funding constraints.

- **Minimum or desired state,** which sets the minimum or desired condition or performance levels that must be delivered by an optimized TAM investment strategy.
- **Treatment benefits and costs,** which quantify eligible investment types, their impact on asset condition, performance, or other metrics included in the analysis, and their associated cost.
- **Asset deterioration models,** which reveal the impacts of the lack of investment to asset condition, performance, or other metrics.

Associated Response Templates

A.3.a: Prioritization Factors

A.3.b: Analysis Parameters
Appendix A

Important Terminology

The following terms are used within this section:

- **Cross-asset metrics,** meaning metrics that allow for measurement and comparison of outcomes across asset programs. Cross-asset metrics typically are established based on the agency goals and performance objectives. Examples include benefit, value, need backlog, safety, and operational performance.
- **Investment prioritization factors,** meaning factors that allow individual projects or other asset management investment opportunities to be evaluated against program goals or performance objectives for purposes of investment optimization or prioritization (see examples above).
- **Analysis parameters,** meaning key inputs to agency asset management or investment optimization analysis, such as asset deterioration rates, treatment condition reset values, treatment unit costs, or analysis time horizons.

Section A.4: Metadata Standards

Area A: Specify and Standardize Data

- A.1: Inventory, Condition, and Performance Data Standards
- A.2: Treatments and Work Data Standards
- A.3: Resource Allocation and Prioritization Standards
- **A.4: Metadata Standards**
- A.5: Governance Standards

Standard formats and processes for documenting data element definitions and calculations, as well as dataset level information, ensure that data are well understood and useful to TAM staff, IT staff, and data users. Accurate, accessible metadata enables users to identify data sources and elements that are available across the enterprise and to understand their limitations.

Metadata Upkeep

Metadata upkeep is often a challenge for an agency. It is important to ensure that appropriate procedures, roles, and responsibilities are in place for adding, changing, or deleting metadata items. Additionally, the DOT must consider what metadata management tools (such as a web-based metadata repository) are needed to ensure efficiency in recording and sharing.

Data Dictionary Standards

When establishing standards for data dictionary metadata, staff can consider available national/international standards (e.g., ISO 19115 and other supplemental IS191** series standards). The following are standardized attributions for a data dictionary:

- **Application, system, table,** and **field names,** which identify unique names and/or identifiers to the associated IT application, specific table, and associated field associated with the data dictionary entry;
- **Description,** a meaningful description of the documented field or data element;
- **Required,** indicating whether the field is required during data entry or can be left unfilled;
- **Field type and requirements**, which capture information relating to the nature of the information being stored in the field, such as the field type, length, precision, or acceptable values;
- **ID/key/uniqueness**, which captures whether the field is a primary or foreign key, or is otherwise required to be unique;
- **Confidentiality/sensitivity,** which classifies the potential confidentiality or sensitivity of the information contained in the field (for example, if it contains personally identifiable information);

- **Usage**, which documents any particular context or limits to the use of the data in the field; and
- **Associated business terms,** which identify what business terms or concepts are represented by the field.

Dataset- or Database-Level Standards

When establishing standards for dataset-level metadata, consider the following standardized attributions:

- **Application or system name,** which is a unique name and/or identifier of the IT application or system or that which is associated with the dataset;
- **Owner/steward,** typically a business point of contact or subject matter expert;
- **Creation/update dates,** which indicate the date when the dataset was created or last updated;
- **Security/sensitivity,** which categorizes the security or sensitivity level of the dataset or system; and
- **Acceptable uses,** which document the acceptable uses of the system or dataset.

Associated Response Templates

A.4.a: Data Dictionary Standards and Guidelines

A.4.b: Dataset Metadata Standards and Guidelines
Appendix A

Important Terminology

The following terms are used within the assessment and improvement identification materials associated with this section:

- **Metadata,** referring to data that provides information about other data. This information can be technical (e.g., field names and formats) or business-oriented (e.g., data definitions);
- **Data catalog,** referring to a listing of available data resources complied to facilitate discovery and understanding; and
- **Data dictionary,** referring to a table documenting individual data elements in a dataset containing information such as data element name, description, and type.

Area A: Specify and Standardize Data

A.1: Inventory, Condition, and Performance Data Standards

A.2: Treatments and Work Data Standards

A.3: Resource Allocation and Prioritization Standards

A.4: Metadata Standards

A.5: Governance Standards

Section A.5: Governance Standards

Formal policies and procedures, oversight structures, roles, and processes are critical for data standards development and adoption. Data governance standards help to ensure that the data collected and maintained by the DOT are well understood, used appropriately, and are effectively and efficiently collected and leveraged across the enterprise.

Governance of Complex Data-Informed Business Processes

Implementing or advancing data-informed TAM business processes will increase the amount, complexity, and integration of data collected and managed by the agency. Data management challenges will grow as practices advance upward through the benchmark levels, with each level requiring increased emphasis on governance to sustain advanced practice.

Data Governance Structure

A commonly used governance structure consists of an upper-level committee that establishes governance policy and direction and is supported by one or more lower-level committees (**Figure I-6**). These governance committees establish data stewardship roles to provide accountability for data within individual business units, functional areas, and/or data subject areas. (For brief descriptions of these data stewardship roles, see the conceptual examples in the text box.)

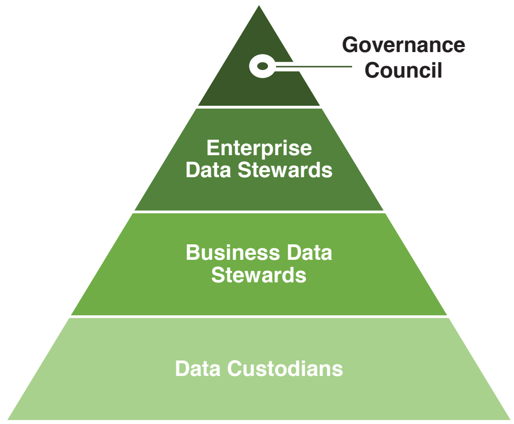


Figure I-6. Example Data Governance Structure.

Conceptual Examples

Data Governance Roles and Responsibilities

Upper-Level Policy Committee (e.g., Governance Council)

The Governance Council is a decision- and policy-making authority, typically reporting directly to high-level executive management, providing oversight and direction to the enterprise governance program.

Technical Working Committee (e.g., Enterprise Data Stewards Committee)

The Technical Working Committee develops governance policy, standards, practices, and guidance; addresses implementation issues; and promotes adherence within the agency.

Enterprise Data Stewards

Enterprise data stewards represent enterprise-level interests in data within specific subject areas, facilitating coordination and agreement across business units.

Data Stewards

Data stewards are accountable for data within a specific business area, working with individual business owners to ensure that the data are well managed and provide value to the organization.

Data Custodians

Data custodians are the technical staff who work under the direction of the data steward and are responsible for execution of governance and data management activities by supporting direct entry, quality control, and maintenance of the data.

Data Governance Policy

Agencies can adopt policies that establish data governance roles and responsibilities, and to ensure that data is treated as an agency asset. Such policies can define data of agency-wide interest and lay the groundwork for data standardization and other processes to ensure coordination across business units on data collection and development.

Associated Response Templates

A.5.a: Data Stewardship

A.5.b: Data Standards and Guidelines Development/ Adoption Processes

A.5.c: Data Collection Approval/Coordination Processes

A.5.d: Change Control (Systems and Data) Processes
Appendix A

Important Terminology

The following terms are used within this section:

- **Data governance,** describing the roles and lines of accountability for the management of an organization's data assets to achieve its business purposes and compliance with any relevant legislation, regulation, and business practice;
- **Data stewardship,** describing the formal, specifically assigned and entrusted lines of accountability for business responsibilities (as opposed to IT responsibilities), ensuring effective control and use of data and information assets;
- **Community of interest,** referring to a group of stakeholders with a common interest in a type of data or another topic area and which, in contrast to a community of practice (wherein members have similar job functions), members may come from different parts of the organization and have distinct goals; and
- **Change management or change control,** referring to processes in place to review, evaluate, and coordinate changes to data products, applications, and systems, and intended to minimize impacts to users and reduce any change-related errors.

Area B: Collect Data

Area B: Collect Data

B.1: Inventory, Condition, and Performance Data Collection

B.2: Project Information Collection

B.3: Maintenance Information Collection

B.4: Priority Criteria and Values Collection

This area addresses the collection of asset inventory, condition and performance data, treatment and work history data, and information about external decision-maker and public perceptions in a manner that can be incorporated into DOT TAM programs.

Area Overview

Area B is organized into four distinct sections:

- **B.1: Inventory, Condition, and Performance Data Collection,** covering the collection of asset inventory, condition, and performance data, together with specific consideration of coverage, automation, and quality;
- **B.2: Project Information Collection,** covering the collection of project work accomplishments to update asset inventory and maintain the work history for specific assets, with a focus on data collection coverage, automation, and quality;
- **B.3: Maintenance Information Collection,** covering the collection of maintenance work accomplishments to update the asset inventory and maintain the work history for specific assets, with a focus on data collection coverage, automation, and quality; and
- **B.4: Priority Criteria and Values Collection,** addressing the capture of public perceptions and decision-maker values to help guide DOT TAM decision-making.

Improvements in this area are aimed at advancing methods for collecting and assuring the quality of key data supporting TAM analysis, reporting, and decision-making. Improvements may include the deployment of innovative technology solutions, as well as improved quality control and assurance techniques and streamlined business processes.

Section B.1: Inventory, Condition, and Performance Collection

Understanding asset inventory, condition, and performance is fundamental to TAM. Data collection activities must be planned to ensure that the right data are gathered with sufficient quality to support decision-making. Data collection is costly, so agencies must carefully manage scope and work to achieve efficiencies.

Data Collection Program Review

Most transportation agencies have programs in place for collecting inventory, condition, and performance data; however, needs and requirements change over time, as technology advances and new data sources create opportunities to improve efficiencies. Periodic review of data collection programs across assets is helpful to determine if adjustments are warranted. Key questions include:

- What data collection is happening now, and how can those processes be automated?
- What information is available in other departments that could be brought into the data collection program?

Quality Management and Governance

A comprehensive Data Quality Management Plan (DQMP) enables a consistent collection process across assets and departments. The development of a DQMP can begin with individual assets and be expanded and integrated over time. Governance processes should also be put into place to ensure that data collection and quality control measures remain aligned with business processes and needs.

Digital Transformation and Automation

As asset collection is standardized, manual and paper processes can be replaced by digital systems and automated processes. Agencies with several disparate collection and management tools can find opportunities for consolidation. Examples of network-level and project-level data collection are discussed in the "Conceptual Examples" text box.

Conceptual Examples

Network-Level Collection

Mobile LiDAR

Data for multiple asset categories (e.g., pavements, roadside assets, signage, marking, drainage) can be bulk-captured using mobile LiDAR vehicles. The data can be processed to extract feature inventory, asset condition, and detailed asset attribution.

Project-Level Collection

Destructive and Nondestructive Pavement Investigation

Project-level data collection for pavements can be informed by destructive methods such as drilling/coring rigs or by nondestructive deflection testing via falling weight deflectometers. Ride quality can be measured using tools such as a high-speed profiler.

Area B: Collect Data

B.1: Inventory, Condition, and Performance Data Collection

B.2: Project Information Collection

B.3: Maintenance Information Collection

B.4: Priority Criteria and Values Collection

Associated Response Templates

B.1.a: Inventory, Condition, and Performance Coverage

B.1.b: Inventory, Condition, and Performance Automation

B.1.c: Inventory, Condition, and Performance Quality

Appendix B

Data Sourcing and Collection Opportunities

Evaluate existing data sources before developing a new data collection program. If new or additional data collection is needed, consider whether outsourcing would be more sustainable than establishing a new, internal data collection program.

Important Terminology

The following terms are used within this section:

- **Data Collection Plan,** referring to an initiative or program planning document that outlines how a data collection program will be executed and improved to meet identified business needs. This plan should attempt to make the best use of current resources to leverage capital investment and technology, and it should be guided by documented business cases and value for data collection.
- **Data Quality Management Plan (DQMP),** referring to a documented management system that details the quality objectives and controls to be applied during the various phases of asset data collection. Its purpose is to ensure quality in all work processes, products, and outputs, and to support continuous quality improvement. Management sponsorship and governance is critical to ensuring the success of the plan.

Area B: Collect Data

- B.1: Inventory, Condition, and Performance Data Collection
- **B.2: Project Information Collection**
- B.3: Maintenance Information Collection
- B.4: Priority Criteria and Values Collection

Section B.2: Project Information Collection

Agencies track information about capital projects from planning through construction phases. If properly structured, this information can be leveraged within TAM to update asset inventories and condition projections and to maintain asset-specific work histories that can be used to better understand asset performance.

Network-Level Tracking

Program-level asset investments and accomplishments may be quantified from project scoping documentation. Typically, this information is only useful for the primary asset in the project and generates limited activity or provides asset-specific information. With this level of detail, project information is useful in estimating general, network-level trends and/or impacts to the TAM program.

Activity-Level Tracking

Project-level asset information often is extracted from project development documents (e.g., contract bid tab information) or project delivery systems used to track contract payments (e.g., AASHTOWare Project SiteManager). Information often is not structured in a manner that can be related to specific assets; however, it provides valuable insight into activity-level investments and accomplishments within the project limits.

Asset-Level Tracking

Tracking project activities against specific project line-items and including asset information (i.e., an asset ID, location, manufacturer, and other details) allows asset managers to understand specifically what assets were impacted or installed through a project. Developing a comprehensive work history for an asset is a valuable support for detailed TAM decision-making.

Project Data Template Creation

Developing project delivery templates that include key assets and standard asset data naming supports data extraction and integration. Some examples related to legacy project data extraction and asset-level project information are provided in the "Conceptual Examples" text box.

Conceptual Examples

Legacy Project Data Extraction

Regulatory Signage Extraction

Standard design templates for regulatory signage can include individual cells or blocks at each sign location, and modern design files are prepared utilizing real local/global coordinate systems. The combination of consistent nomenclature and geo-positional information allows for the automatic extraction of signage assets within a project file for upload to a GIS-based asset management system or asset inventory.

Asset-Level Project Information

Regulatory Signage Asset Information

Project information models that include regulatory signage in a consistent format and with geospatial accuracy enable the automatic extraction of these items. Additional metadata applied to these assets can be extracted alongside the type and location (e.g., installation date, sign dimensions, sheeting material).

Legacy Project Data Conversion

Historical project files contain valuable asset inventory information. Programmatic conversion of these files is an effective means of asset data collection. Useful technologies include:

- **Optical character recognition (OCR) tools,** which are useful for automated recognition of typed, handwritten, or printed text within imagery; and
- **Text analytics and natural language processing (NLP) techniques,** which can be used to process text into useful data.

Important Terminology

The following terms are used within this section:

- **Automated file validation,** referring to specific software created for the purpose of "running" or "processing" project digital files to validate and quality assure information located within;
- **Project data extraction automation,** referring to current or legacy digital project files that contain asset and non-asset information; and
- **Project data templates,** referring to pre-populated project files that include asset types and standard asset information. Using these templates to begin projects enables better quality management and consistent delivery of asset information.

Associated Response Templates

B.2.a: Project Information Coverage

B.2.b: Project Information Automation

B.2.c: Project Information Quality

Appendix B

Section B.3: Maintenance Information Collection

Capture of standard maintenance work order and accomplishment information can provide valuable insights for asset life-cycle planning and maintenance budgeting.

Digital Work Order Data Collection

Field maintenance forces have a unique opportunity to capture needed asset information while on-site. Traditionally, DOT maintenance programs have been delivered through manual (often pen-and-paper) business processes. Converting to a digital work order process or a Computerized Maintenance Management System (CMMS) can bring uniformity and efficiencies to these tasks. Using digital tools also supports the development of a useful, comprehensive work history.

Area B: Collect Data

B.1: Inventory, Condition, and Performance Data Collection

B.2: Project Information Collection

B.3: Maintenance Information Collection

B.4: Priority Criteria and Values Collection

Mobile Data Collection

Mobile data collection devices and applications significantly improve the quality of field-collected information. These tools offer simplified data collection and share valuable reference information. Built-in GPS and GIS capabilities support accurate location against aerial imagery or custom base maps. Field maintenance information also can be directly collected against the asset inventory.

Work Order Automation

Automation of the service request to work order process dramatically streamlines maintenance business processes. As an additional benefit, these techniques improve the accuracy and efficiency of work accomplishment data collection. Examples related to work order management software are provided in the "Conceptual Examples" text box.

Associated Response Templates

B.3.a: Maintenance Information Coverage

B.3.b: Maintenance Information Automation

B.3.c: Maintenance Information Quality

Appendix B

Important Terminology

The following terms are used within this section:

- **Routine maintenance,** referring to maintenance tasks that are planned in advance. These can be recurring tasks or one-off scheduled preventive-care tasks.
- **Service requests,** referring to asset-repair requests that are filed due to damage or wear. These requests can originate from inside or outside an agency.
- **Computerized Maintenance Management System (CMMS),** referring to software that is used to manage an organization's maintenance operations.
- **Work orders,** referring to authorized maintenance tasks. Work orders can result from approved service requests or be generated as part of planned preventive or routine maintenance schedules.

Area B: Collect Data

B.1: Inventory, Condition, and Performance Data Collection

B.2: Project Information Collection

B.3: Maintenance Information Collection

B.4: Priority Criteria and Values Collection

Section B.4: Priority Criteria and Values Collection

Although many TAM decisions are based on technical factors such as condition indices, it is important to put processes in place to understand both asset-user and decision-maker values and priorities. These values and priorities can be used to inform the appropriate use of technical information for decision-making.

Public Perceptions

The public's perceptions and priorities for transportation infrastructure are a critical component of long-term TAM planning and strategic TAM prioritization.

Data collection about the public's perceptions and priorities can begin through ad hoc engagement, during individual public meetings, or with targeted surveys. In more-advanced applications, these techniques should be coordinated and refined into standardized, continuous feedback programs.

Valuable tools to collect data on public perceptions include:

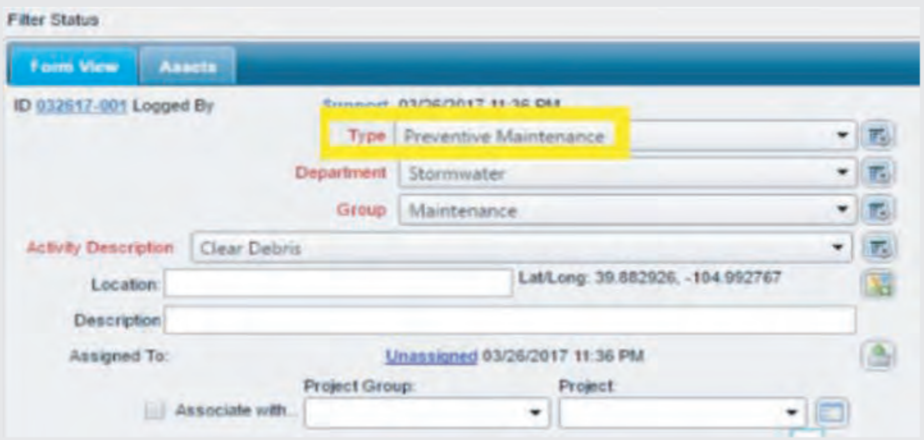
- **Focus groups,** in which small, diverse groups of people are directly engaged to gather feedback;
- **Surveys and polling,** conducted to gather broader samples of public opinion;
- **Social media outreach,** offering two-way communication with the public regarding TAM priorities and values; and
- **Public meetings,** scheduled to directly engage interested members of the community regarding the TAM program.

Conceptual Examples

Work Order Management Software

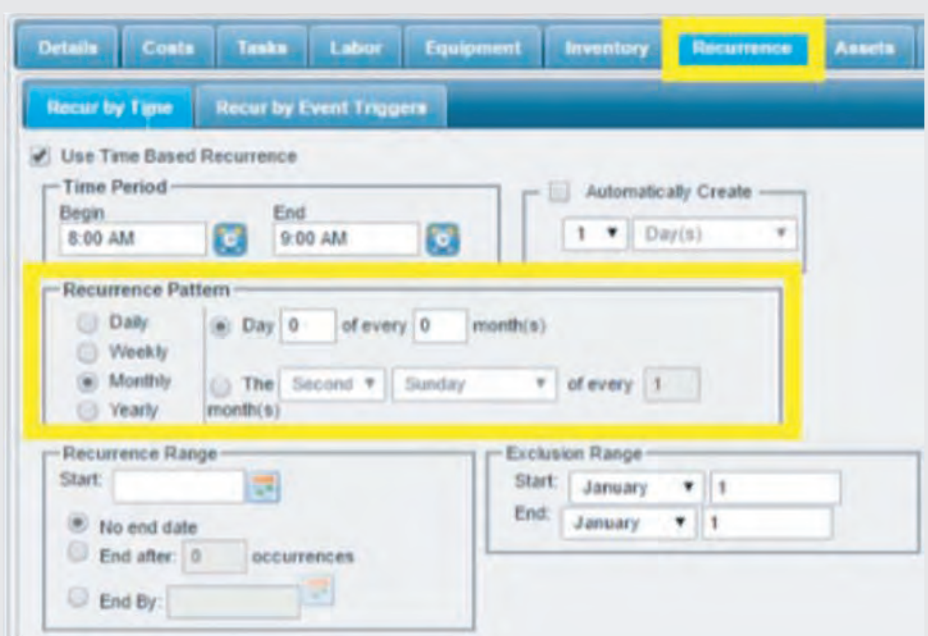
Work Association with Asset and Organizational Structures

Transforming traditional maintenance programs to a centralized CMMS will allow association of maintenance work accomplishments with organizational, work, and asset hierarchy.



Automated Work Ordering

A simple example of work order automation is through the use of scheduling tools to generate recurring work orders for routine maintenance activities.



Agency Values and Perceptions

Internal agency perceptions and leadership values are additional data points that are needed to plan asset management capital programs. These values and perceptions can include requirements that originate from historical/legacy organizational structures as well as from political influences affecting executive leadership.

Decision-makers should be targeted using a structured approach. Some example tools and approaches are:

- **The Delphi technique,** a structured, interactive approach to building consensus among panels of experts;
- **The nominal group technique,** a group problem-solving and decision-making process that promotes consideration of all opinions and is useful in groups of various sizes; and
- **Decision trees,** which are used to map observations and conclusions about decision processes and priorities.

Insights and Value Criteria

Modern decision science and data analytics programs require more than inventories and conditions to provide long-term value. The information obtained from public and agency perception surveys provide required context to support investment decisions. Examples of two approaches to outreach and engagement are described in the "Conceptual Examples" text box.

Conceptual Examples

Customer Service and Social Outreach

Tying the Public Facing Side to Maintenance

DOTs can utilize their customer service centers to tie feedback directly into work orders and maintenance functions. Many public interactions take place on Twitter, Facebook, or other social media outlets. Agencies can introduce ways to connect feedback and maintenance issues into their data collection systems.

Targeted Focus Group Engagement

Capital Plan Roadshows

Some agencies may decide to take their capital improvement plan and budget on the road. Targeting a series of town hall-style public outreach sessions and/or focus groups sessions is an effective means of obtaining a regionally varied input into a transportation asset management capital program.

Associated Response Templates

B.4.a: Public Perceptions

B.4.b: Decision-Maker Values
Appendix B

Important Terminology

The following term is used within this section:

- **Decision science,** referring to quantitative techniques that are used to inform decision-making by identifying optimal choices based on available information. Decision science seeks to make plain the scientific issues and value judgments underlying these decisions and to identify tradeoffs that might accompany any particular action or inaction.

Area C: Store, Integrate, and Access Data

This area involves structuring, integrating, and providing access to data to support TAM operations, management, and reporting needs.

Area Overview

Area C is organized into four distinct sections:

- **C.1: Databases,** covering the design of TAM databases to support efficient and effective storage of and access to contained data and documentation;
- **C.2: Asset Life-Cycle Data Integration Workflows,** covering the efficient exchange of information across various business processes, tools, and systems involved in the complete asset life-cycle from project planning through delivery and ongoing asset management and operation;
- **C.3: Other Data Integration Workflows,** covering the efficient exchange of information between asset management and financial and other supporting business systems and practices; and
- **C.4: Data Access,** covering the ability of agency field staff and the general public to efficiently and securely access TAM information.

Improvements in this area are aimed at efficiently managing asset data and integrating data across systems supporting different assets and different asset life-cycle phases and agency business processes.

Implementation Support

Organizational Practices
Chapter 5

Case Studies
Chapter 5

Section C.1: Databases

Making data available across the enterprise while eliminating redundant information is critical to driving efficiency and reliability. Moving from paper-based data to fully integrated databases also requires planning and critical thinking about how and where the data will be stored, and how different databases will be linked to each other.

Data Storage Management

Data retention, backup, and disaster recovery are essential to the sustainability of agency asset databases and the continuity of critical, data-informed TAM business processes. It is important to examine and quantify risks and select tiered data storage solutions that align with the agency's risk tolerance and budget.

Examples of key components of a Disaster Recovery Plan are provided in the "Conceptual Examples" text box.

Source Systems and Master Data

The agency should identify and designate the source systems in which essential agency business information (such as agency assets, financials, contracts, or employees) will be gathered and stored. A best practice is to create master data from the source data to (1) provide a single "source of truth" for reporting, (2) protect source data integrity, and (3) ensure that changes to source data are reflected in replicated or derivative datasets.

Asset Identifiers and Linear Referencing for Data Linkages

Asset identification and linear referencing schemes are vital to agency database integration. New and existing TAM databases should be structured to provide these standardized data linkages. This practice will enable integration of asset and non-asset data for TAM analysis and decision-making.

Conceptual Examples

Components of a Disaster Recovery Plan

Summary

The summary takes a few pages to cover the most important steps of the plan and key contacts. A stand-alone Executive Summary document also may be prepared.

Scope and Purpose

This section provides an introduction that describes the purpose and scope of the plan along with documentation of authority and approvals and the frequency of review and updates required for the plan.

Roles and Responsibilities

This section provides descriptions of the key roles and responsibilities of each member of the disaster recovery team and any limitations based on governance and approval thresholds.

Response Procedures

This section describes the processes to be initiated and followed in the disaster response, including assessment of the situation, documentation of any damages, and notifications required based on severity of the damages.

Documentation Requirements

This section provides clear directions for the documentation of activities as required if the plan is activated.

Establishing these data linkages typically requires programming; however, more and more commercial software tools are providing end-user utilities to help automate development, decreasing reliance on staff with specialized skillsets.

Data Warehousing

Across the enterprise, asset and non-asset data commonly are stored in different systems. A data warehouse is a central repository of integrated data that supports efficient reporting and analysis. Data typically will be loaded into a data warehouse through automated routines that run on a set frequency based on end-user requirements.

Important Terminology

The following terms are used within this section:

- **Linear referencing system (LRS),** referring to a method used for spatial referencing of the locations of physical features along a linear element. LRS features are described in terms of measurements from a fixed point, such as a mile marker or station along a road. Each feature is located by either a point (e.g., a signpost) or a line (e.g., a no-passing zone). A well-governed LRS helps ensure that the spatial relationships between assets held in different databases can be viewed and analyzed.
- **Data lake,** meaning a single repository of different databases held in native form, which is typically used for data exploration rather than routine analysis. When implementing a data

Associated Response Templates

C.1.a: Efficient Storage

C.1.b: Database Linkages

C.1.c: Document Linkages

C.1.d: Data Storage Capacity

Appendix C

lake, it is important to consider the desired end-uses and such details as storage, security, agility, and end-user sophistication.

- **Disaster Recovery Plan,** referring to a specific plan that documents a set of policies and procedures that support the recovery of data and data infrastructure in the event of a natural or human-made disaster. In the context of asset management, the Disaster Recovery Plan should consider necessary access to data related to life-line assets such as evacuation routes, utilities, and communications.
- **Cloud storage,** referring to an arrangement by which the physical storage of data is managed by an external service provider (e.g., Amazon Web Services or Microsoft Azure). Cloud storage often provides lower cost and less direct maintenance, but requires additional data access and security considerations. Cloud storage has emerged as a useful tool to address rapidly growing data storage needs.

Section C.2: Asset Life-Cycle Data Integration Workflows

Area C: Store, Integrate, and Access Data

C.1: Databases

C.2: Asset Life-Cycle Data Integration Workflows

C.3: Other Data Integration Workflows

C.4: Data Access

Through technology advancement, it is now possible for data to persist across the asset life-cycle (i.e., from planning through to design and delivery and ultimately through to operations and maintenance). Integrating workflows between the various phases of the asset life-cycle is critical to unlocking the value that is amassed through these phases (see **Figure I-7**).

Asset Life-Cycle and BIM for Transportation

BIM for Transportation has emerged as a process that supports asset life-cycle data integration. As technology has evolved to be more and more interoperable, more industries and

Figure I-7. Example data and information flow supporting asset registry development and maintenance.

agencies are seeing the advantages of leveraging BIM—and a common data environment—to support the asset life-cycle from beginning to end.

Project Planning

Asset information that has been developed during project planning and design can seamlessly flow through to the construction and operations phases, generating efficiencies in each project phase and yielding a detailed asset information model to inform asset operation and maintenance.

During project planning, key decisions are made regarding site location, constructability, and regulatory requirements. Assets within the project limits may inform planning decisions. For example, federal project requirements may dictate that safety assets (e.g., guardrails) must be evaluated and brought to current standards during the project. By integrating existing asset information into project planning systems, these activities can be streamlined and planning outcomes can be improved.

GIS databases and tools are customarily used during planning. GIS data that has been collected and generated during planning regarding boundary constraints, material considerations, or site conditions will be key inputs to the project delivery. It is important to ensure that data workflows from planning to development consider how these data are passed on to create efficiencies in future phases.

Project Development

Project development includes the financing and design aspects of an infrastructure project. Schematic and detailed designs progress the project plan into a constructible state. Designs typically incorporate information about asset location, size, material, type or standard, and other details. Design information can be coded into an owner-specified design model as data that can then be leveraged during project delivery.

Project Delivery

Project delivery encompasses the physical construction of the new asset. During this phase, the information contained in the design model can be carried forward to inform and optimize the construction phase. As-built information also can be captured during project delivery.

Handover/Handoff

When construction has been completed, the asset is handed over for management and maintenance. At this stage, asset life-cycle data integration workflows yield the most significant benefits. Data that has been developed and evolved through the project phases can be transferred directly into the owner's asset data model, providing updated asset inventory, condition, and work history. This data should be subsequently maintained through the owner/operator's asset management systems.

Further discussion of data integration across asset life-cycle stages is provided in the "Conceptual Examples" text box.

Associated Response Templates

C.2.a: Asset Management Data to Project or Work Order

C.2.b: Project Planning to Project Development

C.2.c: Project Development to Project Delivery

C.2.d: Project Delivery to Asset Management Data
Appendix C

Important Terminology

The following terms are used within this section:

- **Asset life-cycle,** covering phases that represent key milestones in the development of the asset, starting with planning, then development, then delivery, and ultimately operation and maintenance;

Conceptual Examples

Data Integration Across Life-Cycle Stages

Project Planning to Project Development

Most planning activity occurs in the 2D space using tools like GIS. Planning tasks include site selection, choosing among alignment alternatives, and conducting an environmental constraints analysis. The information gathered for one aspect of planning (e.g., soil information) can influence another aspect (e.g., material selections or placement of pilings in project design). Interoperability between GIS and design tools affords new efficiencies that can eliminate the need to export/import data to inform design. (One example of an interoperable tool is Esri's Autodesk Connector for ArcGIS). Through such tools, planning data can be shared directly with designers to inform decision-making.

Project Development to Project Delivery

Current DOT practices typically involve disconnected processes during which the design model is discarded and the contractor defines a model optimized for their delivery purpose. These disconnected processes are inefficient and ultimately translate to additional costs for the owner. Alternative delivery methods are creating new efficiencies, but infrastructure owners can take responsibility for defining model requirements throughout the phases of design-bid-build projects.

Project Delivery to Asset Inventory/Condition and Work Orders

When model specifications are defined contractually, the as-built plans can be delivered digitally as as-built models. With model specifications directly aligned with the asset information model, data for the assets that were defined in the as-built model can be imported to supplement the asset inventory. Valuable as-built information (e.g., location, photos, manufacturer-recommended maintenance schedules, and warranties) can be retained for use in maintenance work ordering, warrantee claims, and general asset management and operation.

- **Data transformation,** covering the process of converting data from one format to another, which often is required to support data integration workflows (particularly when different technologies are employed by different users or stakeholders over the asset life-cycle);
- **Batch processing/transfer,** a process that supports mature data integration workflows by allowing for certain data transformation tasks to be performed according to a routine, frequently without human intervention; and
- **Performance targets,** meaning targets based on measurements that are intended to provide evidence or give an indication of an asset's level of service or performance. Performance targets can be directly imposed by regulators or set based on the strategic objectives of an organization. Performance targets can be established to meet a committed minimum level of service to the users of that asset (e.g., smoothness of pavement) or they can be aspirational (e.g., if an organization is trying to enhance the level of service to encourage more use or thwart competition, as by reducing congestion levels on managed lanes).

Section C.3: Other Data Integration Workflows

Information contained in agency financial, traffic monitoring, transportation modeling, and environmental systems supports asset risk analysis and prioritization and improves TAM treatment selection and decision-making.

Demand and Utilization

Traffic monitoring and traffic and demand modeling data can help TAM practitioners understand the current and forecasted level of service required of existing or proposed roadway assets. This information is highly valuable in asset management decision-making, particularly to inform prioritization, selection, and scoping of projects and maintenance work. By establishing a means to integrate measured or modeled demand with the DOT's asset data, the agency can:

- **Improve planning and optimize funding** to coincide with current and forecasted levels of services required to meet user needs;
- **Improve design** of new or reconstructed assets based on existing demand, reducing future TAM needs;
- **Improve maintenance treatment selection** to account for known or modeled demand; and
- **Prioritize decision-making** to deliver maximum value for the public and other TAM stakeholders.

Examples of other data integrations are presented in the "Conceptual Examples" text box.

Conceptual Examples

Other Data Integrations

Use of Demand Modeling Data in Asset Management

Traffic demand modeling provides roadway asset owners with forecasted traffic volumes. Forecasted traffic volumes are used in prioritizing work programs and capital projects. Database considerations that support linking demand models to asset inventory are the key to unlocking integration efficiencies (e.g., by using common location referencing or roadway section identifiers).

Use of Environmental Data in Asset Management

Flooding risk is a key environmental factor considered in TAM. With accurate spatial location referencing for asset data, analysis can be conducted to assess the impacts and risks posed by flooding events. The analysis results can be used to inform prioritization of maintenance procedures, treatment selection, asset design decisions, and may also influence new development decisions.

Environmental Modeling

Environmental systems contain data valuable in understanding asset deterioration, environmental impacts of assets and regulatory requirements applicable to individual projects and maintenance actions. Environmental data often is managed in GIS. Geoprocessing tools can efficiently combine GIS information with the associated assets based on their geolocation.

Financial Register Versus Operational Register

A financial asset register is used to produce financial statements and support long-term financial planning and budgeting. In contrast, the operational asset register, which is typically stored in the asset data model of an asset management system, supports the ability to associate and track work orders and maintenance.

It is important to establish a tie between the financial asset register and the operational asset register to support accurate financial reporting and to leverage asset work order and maintenance history to support financial forecasting and planning.

Associated Response Templates

C.3.a: Financial (Revenue, Budget, and Expenditure) Data

C.3.b: Demand and/or Utilization Data

C.3.c: Environmental Data
Appendix C

Important Terminology

The following terms are used within this section:

- **Two-way data exchange,** meaning bi-directional reading and/or writing of data between two databases (see "Conceptual Examples" text box on "Two-Way Data Exchange");
- **Non-asset data,** meaning data that is contextual to the asset but not directly about the asset. For example, the soil type in the area of a buried utility pipe is not data explicitly about the asset but is highly relevant to how the asset will perform;
- **Data transformation,** covering the process of converting data from one format to another as may be required to support data integration workflows, particularly when different technologies are employed by different users and stakeholders throughout the project phases; and
- **Batch processing/transfer,** a process that supports mature data integration workflows by allowing for certain data transformation tasks to be performed according to a routine, frequently without human intervention.

Conceptual Examples

Two-Way Data Exchange

Exchange Between Financial and Operational Asset Registries

A two-way data exchange between an operational asset registry and a financial asset registry may occur when a new asset is constructed:

- In one direction, the asset value may need to be exchanged from the operational asset registry to the financial asset registry.
- In the other direction, the acquisition cost of an asset, which is stored in the financial asset registry, may need to be exchanged from the financial asset registry to the operational asset registry to support life-cycle cost analysis.

Section C.4: Data Access

Data access must be carefully planned to balance the agency's business needs and public accountability with the need to protect data integrity and mitigate the risks of data misuse or misinterpretation.

Connected and Disconnected Editing

Field maintenance staff need the ability to access, update, or input data in both connected and disconnected environments.

Area C: Store, Integrate, and Access Data

C.1: Databases

C.2: Asset Life-Cycle Data Integration Workflows

C.3: Other Data Integration Workflows

C.4: Data Access

- **Connected editing** requires an internet connection (cellular or Wi-Fi) to be able to read or write data back to a database. In a connected environment, field data can be made available immediately upon collection, allowing efficient coordination with office staff or other stakeholders who are not in the field. Field staff also can access information that would otherwise be unavailable without advance planning (e.g., detailed design files from previous projects or comprehensive asset work histories). Connected editing improves field decision-making and generates significant efficiencies by avoiding unnecessary travel time between field and office locations.
- **Disconnected editing** allows a user to download and store data locally on a mobile device (e.g., in the office or at another location with a reliable internet connection). The user can add to or update the local data on the mobile device and later, once an internet connection is reestablished, upload the enhanced/revised information back to the main database.

If fieldwork requires users to retrieve or collect data in remote areas, disconnected editing options will likely be required to support these activities.

Access Levels and Data Security

Data access and security are more easily managed early on, during system development (i.e., when the system and associated data models can be structured to support the assignment and enforcement of data access or security levels). With proper consideration, data access and security can be controlled at the system level, the application level, or even the database level. Sample questions to aid in determining data access levels are provided in the "Conceptual Examples" text box.

Conceptual Examples

Data Access and Security

Database Access Qualifying Questions

Determining who should have access to different datasets can be a daunting task. Key questions that can serve as a guide include:

- Why does the user need to access the data?
- How will the data be used?
- Is the data being accessed sensitive (i.e., would release of the data pose risks)?
- Does the user need read-only access, or will the user need to update the data as part of their task?

Role-Based Data Access

Role-based data access is an approach to granting or denying access to users based on their designated roles in an organization. By defining roles and responsibilities, the appropriate levels of data access can be granted across enterprise-wide systems.

Data governance programs commonly define such roles and implement oversight to monitor and manage the roles and responsibilities so that they can evolve over time to support the changing data and systems environment of the organization.

Mobile Access

Mobile devices such as laptops, phones, or tablets provide handy means for users to access data when they are away from the primary office environment.

When evaluating mobile access, it is important to consider:

- Security protocols and technical programming that are required to make data and/or tools available;
- Data that are required in the field versus data that are desired or useful only in the office; and
- Agency policies and practices relating to mobile device procurement and personal cell phone use.

The proliferation of mobile technologies offers a perception of ease and convenience, but having too much data or overcomplicated tools can reduce efficiency and create adoption challenges. Industry trends are toward targeting mobile tools for niche functions and employing responsive web design (RWD) on primary applications that make web pages render well on a variety of devices and window or screen sizes to avoid costly additional programming to support mobile device use.

Story Boards and Dashboards

Story boards and dashboards have emerged as key data visualization tools that enhance communications. The ability to use illustrations, maps, charts, and other graphics is critical to effective communication of the complex messages of a DOT asset management program. For example, Esri's GIS story boards with embedded maps and charts can communicate critical asset risk areas or forecasted network-level asset conditions far more powerfully than presenting the same data in written reports and spreadsheets. Similarly, tools such as Microsoft Power BI and Tableau make it easy to mine and present trends for historical asset condition values or projected savings based on various project prioritization schemes to support funding approvals. Such tools also allow a DOT to provide curated access to agency data, which is particularly useful when engaging non-expert or external stakeholders.

Associated Response Templates

C.4.a: Field Access to Data

C.4.b: Public Access to Data

C.4.c: Access Security

Appendix C

Important Terminology

The following terms are used within this section:

- **Firewall,** meaning an IT security system that monitors and controls incoming and outgoing network traffic, screening what is and is not let through based on predetermined security rules. It is essentially a barrier between trusted sources and untrusted sources. Adjustments may be required in firewall security protocols to account for new means of access (e.g., mobile or third-party access to agency systems).
- **Single sign-on (SSO),** referring to technology that facilitates ease of data access across various enterprise applications and network resources through an authentication process that allows access to multiple applications with one set of login credentials. SSO reduces or eliminates the need for users to maintain different user names and passwords for different systems.

Area D: Analyze Data

This area addresses the use of established decision-support tools, techniques, and practices to support the development of actionable information and insights that in turn support decision-making.

Area D: Analyze Data

D.1: Data Exploration, Reporting, and Visualization

D.2: Modeling

Area Overview

Area D is organized into two distinct sections:

- **D.1: Data Exploration, Reporting, and Visualization,** addressing the analytical environment, practices, and tools used within the agency data analysis practice; and
- **D.2: Modeling,** presenting specific asset performance prediction and TAM investment optimization and prioritization methodologies which can be supported through data analysis.

Improvements in this area are aimed at advancing practices for transforming raw data into information that can support decision-making.

Area D: Analyze Data

D.1: Data Exploration, Reporting, and Visualization

D.2: Modeling

Section D.1: Data Exploration, Reporting, and Visualization

Transforming raw data to actionable information requires establishing consolidated data processing, analysis, and reporting environments and tools, as well as standardized reporting procedures and training to support effective data analysis.

Data Analysis Environment

A centralized data analysis environment offers significant time savings, improved analysis quality and trust, and a common platform around which to standardize reporting, visualization, and analysis tools, techniques, and practices.

Agencies can populate this environment with authoritative, curated datasets and develop the standardized data transformations needed to support routine TAM data analysis needs. It is important to provide standardized capabilities and solutions to address ad hoc analysis requirements (e.g., use of a data lake to temporarily expose data for time-bound data exploration activities).

TAM Data Visualization Practices

Standardized data reports and visualizations are effective communication and information-sharing tools. Common visualization techniques include:

- **Straight-line diagraming tools** that simplify the representation of the roadway to provide location referencing context.
- **Performance dashboards** that track and represent agency goals, objectives, and performance measures to guide daily asset management work activities and decisions.
- **Data marts and interactive reporting tools** that provide highly usable, ad hoc reporting functions.

TAM Data Analysis Practices

Many transportation agencies are developing specialized data analysis and data science programs to support TAM and other business areas. Descriptions of analytical techniques commonly leveraged to support TAM are provided in the "Conceptual Examples" text box.

Important Terminology

The following terms are used within this section:

- **Big Data,** meaning data that is too large and complex to be dealt with through traditional data processing applications and methods;

Associated Response Templates

D.1.a: Analysis Environment

D.1.b: Analysis Practices

D.1.c: Analysis Tools

Appendix D

Conceptual Examples

Analysis Techniques Supporting TAM

Geo-Processing

Geospatial information can be used to integrate and compile disparate datasets useful for TAM analysis.

Data, Text, and Process Mining

Techniques can be applied to identify anomalies, patterns, and correlations within the large datasets available to TAM practitioners.

Temporal Analysis

This technique enables examination or modeling of a variable within a dataset over time, which is useful for applications such as asset deterioration modeling, performance trend analysis, investment scenario analysis, and asset work history or use evaluation.

Trade-Off Analysis

This technique facilitates the comparison of investment priorities with fiscal constraints (both within a given asset program, or across multiple programs).

Prescriptive Analytics

Business analytics can be used to find the best course of action for a given situation (e.g., selecting a TAM treatment for a specific location or asset).

Predictive Modeling

Business analytics can be applied to forecast future conditions (e.g., asset condition forecasting).

Predictive Analytics

Data mining, statistics, modeling, machine learning, artificial intelligence, or other techniques can be used to make predictions about unknown future events. These techniques are emerging in DOT practice.

Decision Science

Decision science can be applied to score projects and optimize selections for programming based on benefits, costs, and other measures that are used to assign relative importance. This technique is often seen in multi-objective project prioritization and decision-analysis applications.

- **Business intelligence,** meaning the systems, applications, and processes that change raw data into useful business information;
- **Data science,** meaning the use of scientific methods, processes, algorithms, and systems to extract knowledge and insights from structured and unstructured data; and
- **Data mart,** a scaled-down version of a data warehouse, meeting a particular analytical, reporting, or decision-support need.

Area D: Analyze Data

D.1: Data Exploration, Reporting, and Visualization

D.2: Modeling

Section D.2: Modeling

Agencies are implementing increasingly powerful asset performance models and investment prioritization and optimization techniques to support asset life-cycle planning, project prioritization, and network-level resource allocation.

Asset Performance Models

Support condition- or performance-based management strategies through the development of models to forecast asset performance over time. Transportation agencies can use modeling outcomes to improve asset life-cycle planning strategies selection and TAM investment and resource allocation decisions.

Common asset performance models include:

- **Improvement benefit models** that anticipate future asset condition and/or performance for a given TAM investment; and
- **Asset deterioration models** that forecast future condition or performance of the asset, assuming no TAM investment.

Ideally, development of these models is based on statistical analysis of trusted work and performance history; however, where trusted data are unavailable, expert opinion can be used to develop or refine asset performance models. Used in combination, improvement benefit models and asset deterioration models form the backbone of TAM investment optimization and prioritization analysis. Modeling techniques can be deterministic or probabilistic. Examples of these modeling techniques are provided in the "Conceptual Examples" text box.

Conceptual Examples

Modeling Techniques

Deterministic Modeling

A relatively simple and commonly used modeling approach in TAM, deterministic modeling applies regression analysis to develop "best-fit" equations to characterize asset performance changes over time or based on TAM investment.

Probabilistic Modeling

Useful to incorporate uncertainty by providing a distribution of possible strategies, probabilistic models are most applicable to network-level analysis (such as setting funding expectations or needs) in TAM.

TAM Optimization and Prioritization Analysis

DOT asset management systems are often used to conduct network-level optimization analysis of potential investment strategies or treatment options.

Key inputs to the analysis are:

- **Current inventory and condition information** that is necessary as a baseline for the analysis and to establish the potential investment options;
- **Asset performance models** (as described in the section titled "Asset Performance Models");

- **Treatment rules and costs** that define the conditions under which a specific TAM treatment may be applied (e.g., triggering conditions) and the costs of those interventions; and
- **Analysis parameters,** including the:
  - **Analysis horizon** (the number of years to be analyzed);
  - **Analysis objective** (e.g., to maximize benefit or to minimize treatment cost); and
  - **Analysis constraints** (e.g., minimum performance expectations or maximum funding limits).

For some assets, condition- or performance-based management information may not be available. In these cases, age-based or reactive management techniques can be useful. These approaches can still rely on network-level analysis to prioritize investment options based on available asset information, associated prioritization factors, and existing funding and resources.

Cross-Asset Resource Analysis

The output from asset-specific investment optimizations can be combined and analyzed to identify the optimal distribution of resources across asset and program areas. In this approach, a DOT must relate performance outcomes from individual asset programs to a common benefit or value (typically based on overarching agency goals and objectives). With these relationships established, trade-off analyses can be completed to optimize the total agency benefit or value based on asset-specific outcomes that have been modeled at various potential investment levels.

Important Terminology

The following terms are used within this section:

- **Investment optimization,** referring to analysis techniques applied to select ideal TAM investments for a given analysis horizon, objective, and set of constraints;
- **Investment prioritization,** referring to screening and ranking techniques used to establish TAM investment priorities; and
- **Analysis parameters,** referring to key inputs to agency asset management or investment optimization analysis, such as asset deterioration rates, treatment condition reset values, treatment unit costs, or analysis time horizons.

Associated Response Templates

D.2.a: Asset Performance Prediction

D.2.b: Optimization/ Prioritization

Appendix D

Area E: Act as Informed by Data

This area involves the application of data and information systems, processes, tools, and techniques to TAM decision-making, including performance targeting and prioritization programs, project-level scoping and design, as well as infrastructure and equipment maintenance practices.

Area E: Act as Informed by Data

E.1: Resource Allocation and Prioritization

E.2: Project Planning, Scoping, and Design

E.3: Maintenance

Area Overview

Area E is organized into three distinct sections:

- **E.1: Resource Allocation and Prioritization,** addressing how data are applied within TAM performance targeting and project prioritization;
- **E.2: Project Planning, Scoping, and Design,** presenting how project planning and scoping, as well as design, are informed by data; and
- **E.3: Maintenance,** capturing how available data are incorporated into agency infrastructure and equipment maintenance practices.

Improvements in this area are aimed at better integrating use of data and information within TAM processes including network-level investment decision-making, project-level prioritization and development, and routine maintenance decisions.

Area E: Act as Informed by Data

E.1: Resource Allocation and Prioritization

E.2: Project Planning, Scoping, and Design

E.3: Maintenance

Section E.1: Resource Allocation and Prioritization

Optimizing the allocation of scarce resources is one of the essential goals of a TAM program. As data and analysis methods improve, agencies can prioritize projects and allocate resources based on a firmer, more defensible foundation.

Performance Targeting

Asset performance targets should be:

- **Aligned** with TAM goals, objectives, performance measures, and analysis;
- **Achievable** through existing practices; and
- **Integrated** meaningfully into actual TAM decision-making.

Project Prioritization

Project-level investment decision-making should be aligned with stated agency goals and objectives. A variety of techniques can be employed to support informed maintenance, rehabilitation, and replacement project selection. Examples include:

- **Simple asset information summaries** that expose trends in asset allocations, inventory, condition, and/or performance through business intelligence tools (ideally as formal performance dashboards). By promoting the visibility of performance outcomes, TAM practitioners and management will be encouraged to evaluate and improve existing project-selection practices.
- **Network screening tools,** which are used to evaluate available data (e.g., asset inventory, condition, utilization, risk, or other factors) to identify ideal TAM investments for individual assets or locations.
- **Multi-objective decision analysis** techniques that can be employed to objectively evaluate project costs in relation to the projects' anticipated benefits to agency goals or objectives. Evaluation results should be formally incorporated into decision-making through well-documented procedures that are routinely evaluated against agency priorities.

Examples that illustrate the incorporation of performance targets into TAM decision-making are provided in the "Conceptual Examples" text box.

Associated Response Templates

E.1.a: Performance Targeting

E.1.b: Project Prioritization
Appendix E

Important Terminology

The following terms are used within the assessment and improvement identification materials associated with this section:

- **Cross-asset metrics,** which allow comparison and evaluation of agency performance across multiple asset areas and programs (e.g., in terms of asset need, value, or benefit);
- **Cross-asset resource allocation,** a technique by which potential investment strategies across multiple assets and/or program areas are evaluated to identify an investment program that best meets overarching agency priorities;
- **Multi-objective decision analysis (MODA),** a decision-making process utilized to make the best decision given a complex set of competing criteria and priorities (e.g., as used by agencies in capital project selection). Utilizing an established objective hierarchy and defined value function based on agency goals and objectives, the DOT completes detailed, project-level data collection and analysis to score potential projects and identify those with the highest returns on investment. These projects are then prioritized in programming of available funds.

Conceptual Examples

Performance Target Incorporation into TAM Decision-Making

Agency Strategic Plans

TAM performance targets reflect agency TAM goals, objectives, measures, and targets; document funding expectations, key asset life-cycle practices, and roles and responsibilities; and raise TAM awareness and establish agency direction, priorities, and strategy.

TAM Resource Allocation and Budgeting

TAM performance targets should be aligned with resources by adjusting available resources and budgets or targeted performance as appropriate and necessary.

Performance Dashboards

TAM performance targets guide decision-makers as progress is reported and by supporting course corrections when needed. For this purpose, output measures (e.g., miles paved, bridges rehabilitated) may be correlated to outcome measures that are more difficult to monitor (e.g., percentage of good pavement, number of deficient bridges).

Continual Improvement

TAM performance targets include the identified roles and responsibilities of staff or contracted vendors who have accountability for achieving the targets. Targets are routinely evaluated to support continual improvement of TAM decision-making business processes.

Section E.2: Project Planning, Scoping, and Design

Area E: Act as Informed by Data

E.1: Resource Allocation and Prioritization

E.2: Project Planning, Scoping, and Design

E.3: Maintenance

Asset inventory, condition, work history, and treatment recommendation data are used to support efficient project development, as well as selection of optimal design features to meet maintenance and operational needs.

Project Planning and Scoping

DOT policies often recommend (or even require) that certain asset maintenance, repair, or replacement activities be incorporated within planned capital projects. These requirements often are based on existing field conditions; however, transportation agencies often have limited formal tools to support informed decision-making.

Typically, simple checklists are developed to support these processes. Agencies should seek to improve scoping by integrating available asset inventory, condition, and performance information directly into project planning.

Incorporation of Optimization and Prioritization Analysis

Transportation agency asset management systems are often used to conduct network-level optimization analysis of potential investment strategies or treatment options (further detailed in the support materials in this chapter for Area D).

Agencies are often challenged to meaningfully incorporate outcomes from network-level TAM optimization analysis into project-level decision-making. Policy, procedures, and tools are all necessary to overcome these challenges; however, they must be balanced by recognition of the reality that project-specific field conditions cannot be fully accounted for in network-level analysis. It is important that appropriate flexibility be offered to decision-makers in the field.

Field Performance Verification

Transportation agencies can monitor asset condition and performance after project delivery to validate actual versus predicted outcomes. If significant discrepancies are observed, analysis can help determine if design or construction practices can be improved or if asset performance models should be adjusted. An approach of continual monitoring and improvement benefits design and construction practices, project-level decision-making, and network-level TAM analysis.

Examples that illustrate the incorporation of TAM analysis in project-level decision-making are provided in the "Conceptual Examples" text box.

Conceptual Examples

TAM Analysis Incorporation in Project-Level Decision-Making

Treatment Selection Screening

Prescriptive decision-analysis techniques can be applied to individual assets or potential investment locations to establish acceptable treatment categories. These techniques are very useful in preventive maintenance scoping, where certain field conditions may be known to result in low performance benefits (e.g., application of preventive maintenance seal coats to pavements exhibiting fatigue or "alligator" cracking).

Network-Level "Best Mix of Fixes"

Predictive modeling and analytics can provide optimized TAM investment strategies. Rather than applying modeled outcomes directly to specified locations, it is useful to aggregate outcomes by treatment or activity type. Then, the agency can communicate the investment targets to field decision-makers and allow field selection of the specific locations and detailed TAM treatments or activities.

This approach balances the optimal strategies with the field realities that are not accounted for in the network-level analysis. Predictive modeling and analytics also can be paired with treatment selection screening to ensure that the field-selected treatments are appropriate to the specific locations selected.

Associated Response Templates

E.2.a: Data-Driven Project Planning and Scoping

E.2.b: Data-Driven Project Design

Appendix E

Important Terminology

The following terms are used within this section:

- **Project scoping templates,** as developed for common project types, can be pre-populated with TAM analysis outcomes and asset inventory and condition information as the basis for field project scoping. These templates provide efficiencies in scoping activities and encourage investment decisions aligned with TAM priorities.

- **Evidence-based design and construction,** meaning the use of a scientific methodology and statistical techniques to evaluate project design decisions and construction practices to achieve the best possible outcomes. Evidence-based design and construction can be useful to TAM programs in identifying changes to design standards and processes that support improved asset management and operations outcomes.

Section E.3: Maintenance

Asset life-cycle modeling techniques can be used to develop effective routine, preventive, and reactive maintenance programs for transportation infrastructure and equipment.

Common Maintenance Practices

Most agency equipment and many transportation assets have well-documented standards for routine and preventive maintenance. Equipment manufacturers recommend regular preventive maintenance cycles (e.g., oil changes or tune-ups) and many DOTs, other transportation asset owners, or industry representatives have recommendations for when various transportation assets should be inspected or receive preventive care. These practices can be incorporated into DOT life-cycle models and maintenance programs. By investing in these activities, even following a defined, interval-based methodology, the DOT can expect to generate long-term savings through improved performance and extended service life. Examples that promote awareness of standard operating procedures, targeted communication and outreach, and performance targets are provided in the "Conceptual Examples" text box.

Conceptual Examples

Promoting Awareness

Standard Operating Procedures

Agencies can identify targeted routine and preventive maintenance activities and document clear standard operating procedures for maintenance staff. It is advisable to share this documentation in an easily accessible location and to advertise its availability. For complex activities, agencies can consider establishing formal training courses to ensure proper application.

Targeted Communication and Outreach

DOTs can organize regular meetings with field maintenance staff to promote awareness of preventive and routine maintenance expectations and opportunities, and to share anticipated outcomes and benefits of these practices.

Performance Targets

Using life-cycle modeling, interval-based methods, or available funding, DOTs can establish and track preventive maintenance targets. It is important to validate that maintenance efforts are being targeted to appropriate candidate assets or equipment (as preventive maintenance is typically only useful to extend the life of an asset that is still in good condition).

Automated Work Ordering

To the extent that asset management and work ordering systems can be integrated, agencies can implement tools to automatically screen the asset inventory for routine, preventive, and reactive maintenance candidates. When assets have been identified, the integrated system can automatically generate and assign work orders to trigger necessary maintenance activities.

Associated Response Templates

E.3.a: Infrastructure Maintenance

E.3.b: Equipment Maintenance

Appendix E

Important Terminology

The following terms are used within this section:

- **Automated work ordering,** an automated process that generates maintenance work orders that are typically based on asset use, age, maintenance or work logs, inspection results, observed defects, or condition ratings;
- **Preventive maintenance,** meaning programs or activities that employ a network-level, long-term strategy that enhances asset performance or extends asset life through a set of proactive, cost-effective practices; and
- **Routine maintenance,** meaning recurring maintenance activities that are regularly employed over the life of an asset (e.g., cyclical inspection, servicing, or replacement of components).