NCHRP 08-36, Task 114
Transportation Asset Management for Ancillary Assets

Requested by:

American Association of State Highway and Transportation Officials (AASHTO)
Standing Committee on Planning

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April 16, 2014

The information contained in this report was prepared as part of NCHRP Project 08-36, Task 114, National Cooperative Highway Research Program (NCHRP).
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Acknowledgements

This study was conducted for the AASHTO Standing Committee on Planning, with funding provided through the National Cooperative Highway Research Program (NCHRP) Project 08-36, Research for the AASHTO Standing Committee on Planning. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 08-36 is intended to fund quick response studies on behalf of the Standing Committee on Planning. The report was prepared by David Rose, Ph.D., Keyur Shah, John Patrick O'Har, Ph.D. of Parsons Brinckerhoff and William Grenke, Independent Consultant. The work was guided by a technical working group that included:

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EXECUTIVE SUMMARY

There is a considerable body of knowledge and research related to the asset management of pavement and bridge assets. The application of established asset management principles to pavement and bridge assets has helped increase pavement and bridge service life and improved resource allocation. Thus far, these asset management principles have been applied to ancillary assets, i.e., non-pavement and bridge transportation infrastructure assets, to a much lesser extent, but can be applied to such assets more broadly and rigorously. The ancillary asset management guidance provided in this report supplements *NCHRP Synthesis 371* and is not prescriptive, but can provide the foundation for the development of asset management plans for selected ancillary assets.

The purpose of this research is to provide guidance on the application of asset management to selected ancillary assets. The research develops an ancillary asset classification hierarchy that can be used as a common starting point for state Departments of Transportation (DOTs) to use in their enterprise approach to asset management information when establishing inventories of ancillary assets and developing management systems for these assets. The state-of-the-practice in transportation asset management at DOTs is moving towards the implementation of Enterprise Asset Management Systems (EAMS) – these are asset information systems with technology architectures that vary by state. EAMS integrate data from multiple systems, which allows for better data reporting, decision-making, and results in overall improvement in asset management system effectiveness.

The literature on the state-of-the-practice shows a range of maturity as it relates to the application of asset management principles to ancillary assets. Our literature review and scan of the state-of-the-practice as it relates to ancillary asset management indicate that there are no industry standards for asset management of ancillary assets. This report finds that for most State Departments of Transportation (DOTs) ancillary assets are managed at the lowest maintainable unit, which is in conformance with industry standards of practice (see British Standards Institute PAS-55 and ISO 55000); however, there is as yet less integration of the management of these assets across their whole life cycle into programming and budgeting processes nor are there established asset management plans for most of these ancillary assets.

This research report reviews the state-of-the-practice in ancillary asset management, identifies how ancillary asset management can be integrated into Enterprise Asset Management Systems (EAMS), develops an ancillary asset classification hierarchy, and recommends life cycle management business processes for the following asset elements:

- Culverts
- Drainage systems and environmental mitigation features
- Overhead sign and signal structures
- ITS equipment
- Network backbone
- High mast light poles
- Sidewalks and curbs

CHAPTER 1 INTRODUCTION

Asset management of transportation assets extends to all asset classes; assets other than pavements and bridges are categorized as ancillary assets in this report. The report includes the following information as guidance to provide a starting point from which highway agencies can approach asset management for ancillary assets:

- **A classification hierarchy for ancillary assets.** The report provides a generally applicable asset hierarchy for state Department of Transportation (DOT) ancillary assets based on the results of prior research, the evaluation of features inventories and other classification information used by various state DOTs.

- **Identification of how the life cycle management of ancillary assets can be incorporated into enterprise asset management systems.** The inventory and condition data of assets is foundational for asset management. The research identifies emerging strategies for the incorporation of inventory, condition, and other ancillary asset data into enterprise asset management systems.

- **State-of-the-practice for asset management for a subset of ancillary assets.** The document integrates information on the practices used by state DOTs for a subset of the ancillary assets.

- **Recommended life cycle management business processes for the selected ancillary assets.** The project team conducted research into the state-of-the-practice and applied lessons learned at the state level to recommend life cycle management business processes for the subset of ancillary assets that are the focus of this research. These recommended life cycle management business processes can be used as the foundation for the development of asset management plans for these assets.

In particular, this report focuses on a subset of ancillary assets. These assets are:

- Culverts
- Drainage structures
- Overhead sign and signal structures
- ITS equipment
- High mast light poles
- Network backbone
- Sidewalks and curbs

STATE-OF-THE-PRACTICE

There are internationally-accepted standards for the management of physical infrastructure assets. In the United States, there is a considerable body of knowledge associated with the management of pavement and bridge assets. In addition, the passage of Moving Ahead for Progress in the 21st Century (MAP-21) has resulted in new requirements for U.S. transportation agencies related to asset management. Nonetheless, MAP-21 requirements are primarily focused on the asset management of pavement and bridge assets.

In general, there are no industry-accepted standards for the management of ancillary roadway assets. This is not to say that there is no literature that discusses the management of ancillary roadway assets. Much of the existing literature that focuses on capturing the state-of-the-practice related to ancillary asset management discusses maintenance quality of service concepts, or estimates the service lives of ancillary roadway assets. For a thorough review of the relevant existing literature please see Chapter 6: Literature Review.

Research Objective

This research is intended to provide guidance to DOTs on how to implement life cycle management practices for ancillary assets and to incorporate them into an integrated asset management program. This research builds upon and supplements the AASHTO *Transportation Asset Management Guide Volume 2: A Focus on Implementation*. This report is not prescriptive, but rather serves as guidance for transportation agencies in terms of life cycle management of ancillary assets at both the asset class level and within the context of enterprise asset management systems.

The research addresses the following key areas identified by the project panel, stakeholders, and the research team:

1. Provide standards for the classification of ancillary assets.
2. Document state-of-the-practice in ancillary asset management and provide guidance in terms of best practices for ancillary asset life cycle management.
3. Provide guidance on how ancillary assets can be included and incorporated in transportation asset management systems.

Project Approach

The research involved the following steps:

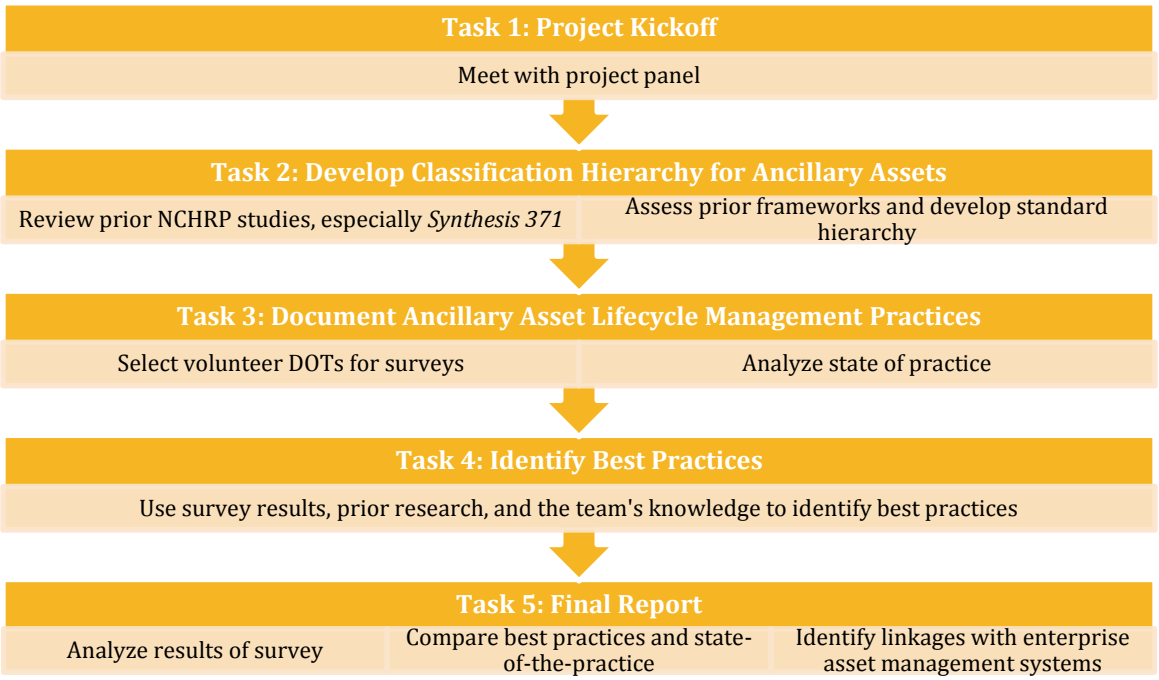
- Task 1: Project Kickoff
- Task 2: Develop Classification Hierarchy for Ancillary Assets
- Task 3: Document Ancillary Asset Life Cycle Management Practices
- Task 4: Identify Best Practices
- Task 5: Final Report

After the kick-off meeting with the project panel, the research team reviewed prior NCHRP studies to gather background information for the development of a classification hierarchy for ancillary assets. The research team contacted selected state DOTs to obtain the asset classification hierarchies in use. Along with the project team's knowledge and expertise, and following a discussion with the project panel and selected state DOTs, the researchers defined an ancillary asset classification hierarchy. This hierarchy built on prior work performed by the team for state DOTs and *NCHRP Report 677: Development of Levels of Service for the Interstate Highway System* (a major component of which addressed maintenance levels of service for maintenance features and ancillary assets).

Next, the researchers distributed questionnaires to selected DOTs and identified state-of-the-practice conditions in terms of ancillary asset life cycle management. The research team then used a combination of existing literature,

survey results, and the researchers' knowledge and roadway asset management expertise to develop guidance, in the form of recommended life cycle management business processes, for a subset of ancillary assets. Figure 1 provides an overview of the major project tasks and key activities in each task.

Figure 1 Outline of Primary Project Tasks



Report Organization

The structure of the remaining chapters is outlined below.

- Chapter 2: Asset Management of Ancillary Assets – discusses how the approach to ancillary asset management in this report is consistent with accepted international standards.
- Chapter 3: Integration of Ancillary Assets into Enterprise Asset Management Systems – describes how the management of ancillary assets can be incorporated into enterprise asset management systems. This includes a discussion of the business processes required for the management of ancillary assets.
- Chapter 4: Ancillary Asset Classification Hierarchy – defines a logical, generally-agreed upon ancillary asset classification hierarchy, which is divided into asset classes, asset elements, asset sub-elements, and also includes definitions.
- Chapter 5: Recommended Life Cycle Management Business Processes for Selected Ancillary Assets – provides guidance for life cycle management activities for the asset elements selected by the Project Panel for further focus. This guidance can serve as the foundation for asset management plans for these ancillary assets.
- Chapter 6: Literature Review – provides a summary of the literature related to the asset management of ancillary assets.

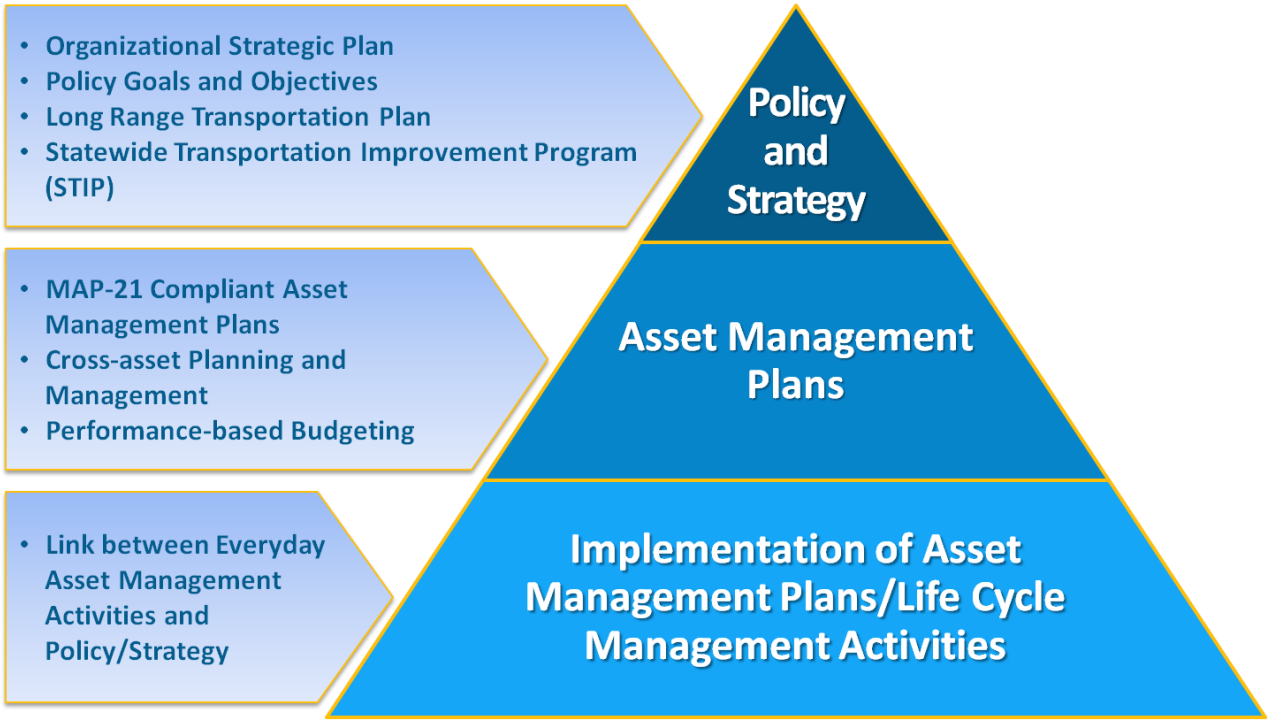
CHAPTER 2: LIFE CYCLE MANAGEMENT OF ANCILLARY ASSETS

This section presents an overview of the life cycle management of ancillary assets, and is intended to provide a common understanding to the report audience. Since there are no particular technical standards or specifications for the management of ancillary assets in the transportation industry, the project team used the terminology and elements of asset management as outlined in Publicly Available Standard (PAS) 55 (IAM 2008a; IAM 2008b) and International Organization for Standardization (ISO) Standards 55000 – 55002 (ISO 2014a; ISO 2014b; ISO 2014c). The PAS 55 standard served as the basis for and will be replaced by ISO 55000-55002 in January 2015 (ISO 2014b; ISO 2014c).

ISO 55000:2014 defines a management system as a set of interrelated or interacting elements of an organization to establish policies and objectives, and processes to achieve those objectives. PAS 55-1:2008 defines asset management information as meaningful data related to assets and asset management; an asset management information system is defined as a system for the storage, processing, and transmission of asset management information (IAM 2008a). The linkage between asset management and information systems is discussed in Chapter 4: Integration of Ancillary Assets into Enterprise Asset Management Systems.

PAS 55 and ISO 55000-55002 define several key elements of management systems for asset management at multiple levels as shown in Figure 2.

Figure 2 Key Elements of Asset Management Systems



International asset management standards and industry best practices define life cycle management activities, which are the foundational elements of an agency's asset management system, at the lowest maintainable unit level. Asset management plans describe the life cycle management activities for specific assets that will help achieve asset management objectives and performance targets. At the policy and strategy level, organizational strategic plans, statewide long-range transportation plans, and the statewide transportation improvement program should be linked to asset management plans.

MAP-21 Requirements and Risk

MAP-21 requires that each State develop a risk-based asset management plan for the National Highway System (NHS) in order to improve or preserve the condition of the assets and the performance of the system. Generally this risk-based asset management plan would include strategies that lead to the development of a program of projects that help make progress toward achieving State targets for asset condition and performance of the NHS and also support achieving national goals. The plan must include the following (FHWA 2012b):

- A summary listing of the pavement and bridge assets on the NHS in the state, inclusive of a description of the condition of these assets
- Asset management objectives and measures
- Performance gap identification
- Life cycle cost and risk management analysis
- Financial plan
- Investment strategies

Although States are only required to include pavements and bridges on the NHS in their risk-based asset management plans, they are encouraged to include all assets within the highway right-of-way such as pavement markings, culverts, guardrail, signs, traffic signals, lighting, Intelligent Transportation System (ITS) infrastructure, rest areas, etc. (FHWA 2012b).

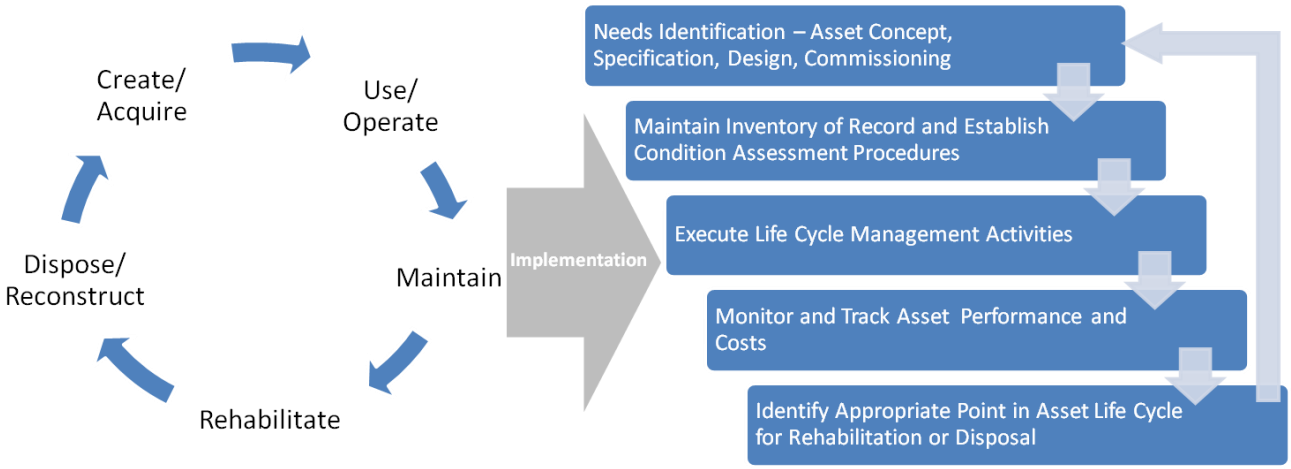
Adopting a risk-based approach for the management of ancillary assets is particularly important. ISO 55000:2014 defines risk as the effect of uncertainty on objectives and encourages organizations to adopt risk-based decision-making processes that balance performance, costs, and risks (ISO 2014a). DOTs typically own and maintain a large quantity and variety of ancillary assets within the highway right-of-way. There is potential to achieve significant economic benefit, in the form of risk reduction and cost savings associated with more efficient resource allocation, by adopting a risk-based approach for ancillary asset management.

Asset Life Cycle Stages and Life Cycle Management Business Processes

This research report addresses the whole life cycle management of selected ancillary assets and their associated business processes. Figure 3 shows the primary stages in an asset's life cycle along with key decision points used

to manage an asset across its whole life cycle. The approach depicted in Figure 3 is consistent with PAS-55 and ISO 55000[1].

Figure 3 Principal Asset Life Cycle Stages and Key Decision Points in Life Cycle Management



In general, the key decision points in the life cycle management of an asset involve the business processes described below in Table 1. These business processes are divided into enterprise-level and asset specific-level sections. Those business processes at the enterprise-level should be considered beyond the context of a particular ancillary asset. For example, inventory business processes should align with enterprise-level inventory processes and procedures.

Enterprise-level

- Inventory
- Interaction between Asset Classes
- Relationship of Asset Class to Overall Safety, Mobility, and Asset Performance

Asset Specific-level

- Inspection and Condition Assessment
- Level of Service/Performance Metrics
- Lifecycle Management Plans and Practices
- Asset Prioritization
- Decision Support

When developing asset management plans, agencies should consider both those business processes at the enterprise-level and at the asset specific-level. The enterprise-level life cycle management business processes capture the interdependencies between and within particular ancillary assets and also between particular ancillary

[1] PAS 55 defines the life cycle of an asset as the time interval beginning with the identification of the need for an asset and terminating with the decommissioning of the asset or associated liabilities. Principal stages of an asset's life cycle include: create/acquire, use/operate, maintain, rehabilitate, and dispose/reconstruct (IAM 2008a).

assets and the overall roadway asset management system. Asset specific-level life cycle management business processes are specific to a particular ancillary asset.

The recommend life cycle management business processes are not prescriptive, but rather serve as guidance and a starting point for the development of asset management plans. In many instances, agencies that can successfully define, understand, and concisely communicate the information contained in these sections are not only able to better prioritize funds but also communicate the level of service or performance that would be delivered through a greater funding level.

Table 1 Life Cycle Management Business Processes

Key Decision Points in Life Cycle Management	Description	Corresponding Life Cycle Management Business Processes
Needs Identification	Examine how an asset affects the overall safety, mobility and performance goals of an agency – asset concept, specification, design, and commissioning	• Relationship of asset class to overall safety, mobility and asset performance
Maintain Inventory of Record and Establish Condition Assessment Procedures	Identify all assets owned by the agency and list these assets in an inventory of record; inspect assets at predetermined intervals and assess their condition	• Inventory • Inspection and Condition Assessment
Execute Life Cycle Management Activities	Conduct asset life cycle management activities as specified in the asset management plan	• Life cycle management plans and practices
Monitor and Track Asset Performance and Costs	Track asset performance against targets and the cost of life cycle management activities over time – use this information to support decision making and prioritize life cycle management activities; identify linkages and interactions between different asset classes	• Level of Service/ Performance Metrics • Asset Prioritization • Decision Support • Interaction Between Asset Classes
Identify Appropriate Point in an Asset's Life Cycle for Rehabilitation or Disposal	As specified in the asset management plan – reexamine how an asset affects the overall safety, mobility and performance goals of an agency and assess suitability for rehabilitation or disposal	• Relationship of asset class to overall safety, mobility and asset performance

CHAPTER 3: INTEGRATION OF ANCILLARY ASSETS INTO ENTERPRISE ASSET MANAGEMENT SYSTEMS

DEFINITIONS

This section establishes common definitions for enterprise asset management, maintenance management, asset management and their associated systems. The term "enterprise asset management" refers to asset management conducted at an enterprise level instead of just one division within an agency – and an "enterprise asset management system" refers to a system or collection of information systems that support enterprise asset management.

The terms "maintenance management" and "asset management" are frequently used interchangeably although they are separate and distinct. The primary purpose of a maintenance management system is work order management to manage maintenance activities (what and when activities are performed on assets, costs of maintenance), while the primary purpose of an asset management system is to provide a more holistic view of all assets, to allow monitoring, tracking, and analysis of how funding strategies affect asset condition, and to allow an agency to make policy and strategic decisions regarding funding (cross-asset resource allocation, investment decision making). Maintenance management should be envisioned as an important subset of asset management that addresses the relationships between maintenance and reliability.

A maintenance management system, when integrated with other business processes and tools, such as condition tracking and forecasting, and other enterprise tools, forms a true enterprise asset management system/tool. An agency's pavement management system or bridge management system, generally, are good examples of maintenance management systems for specific assets.

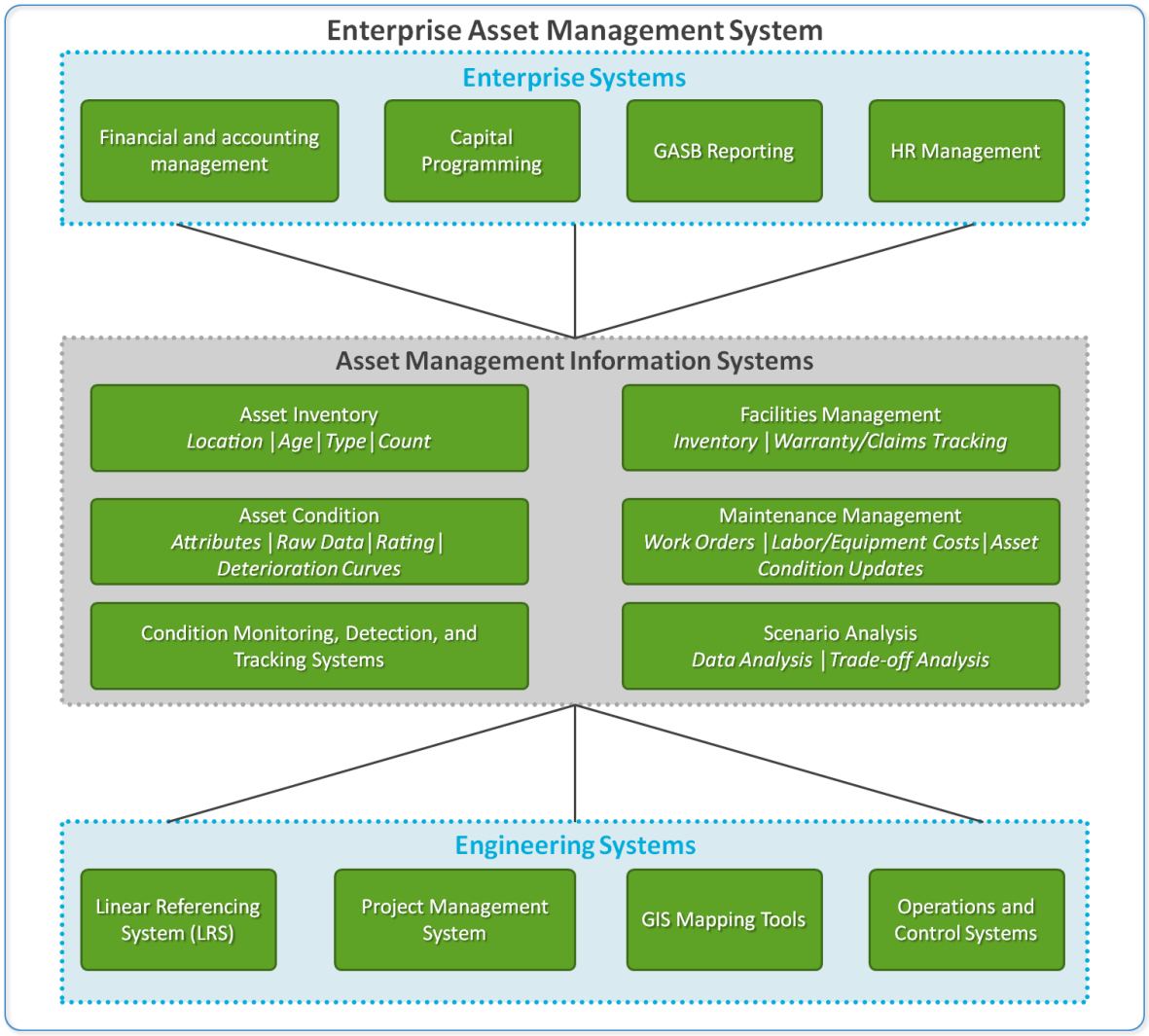
ENTERPRISE ASSET MANAGEMENT TECHNOLOGY

There are a number of technical approaches (technology architectures) for an individual DOT's Enterprise asset management system. For example, it need not be a system that contains data on all assets, but rather multiple information systems and databases that can share data with each other, allowing for more intelligent data reporting and decision making, which are indicative of a more advanced asset management system. Figure 4 presents a conceptual architecture of an enterprise asset management system. As shown in the figure, an asset management information system could be one tool/system that provides all the capabilities (shown in the "*asset management information system"* box) or integrated systems that, combined, provide all these capabilities. An "enterprise" asset management system should integrate with other key agency systems to both send and receive information. GIS mapping tools, for example, allow an agency to display the data visually, while financial and accounting management systems tied to the core asset management system allow for better cost tracking.

In terms of financial and accounting management and GASB reporting requirements, certain ancillary assets, such as variable message signs and high mast light poles, are likely to be considered capital assets. Agencies with asset management systems in place for ancillary assets may choose to adopt the modified approach described in GASB

34 to perform asset valuations. However, the nature of maintenance activities for ancillary assets will likely determine if these maintenance activities are considered expenses or should be capitalized. For example, routine debris removal from catch basins is likely to be expensed whereas the replacement of a variable message sign at the end of its life cycle is likely to be capitalized.

Figure 4 Enterprise Asset Management System Conceptual Architecture



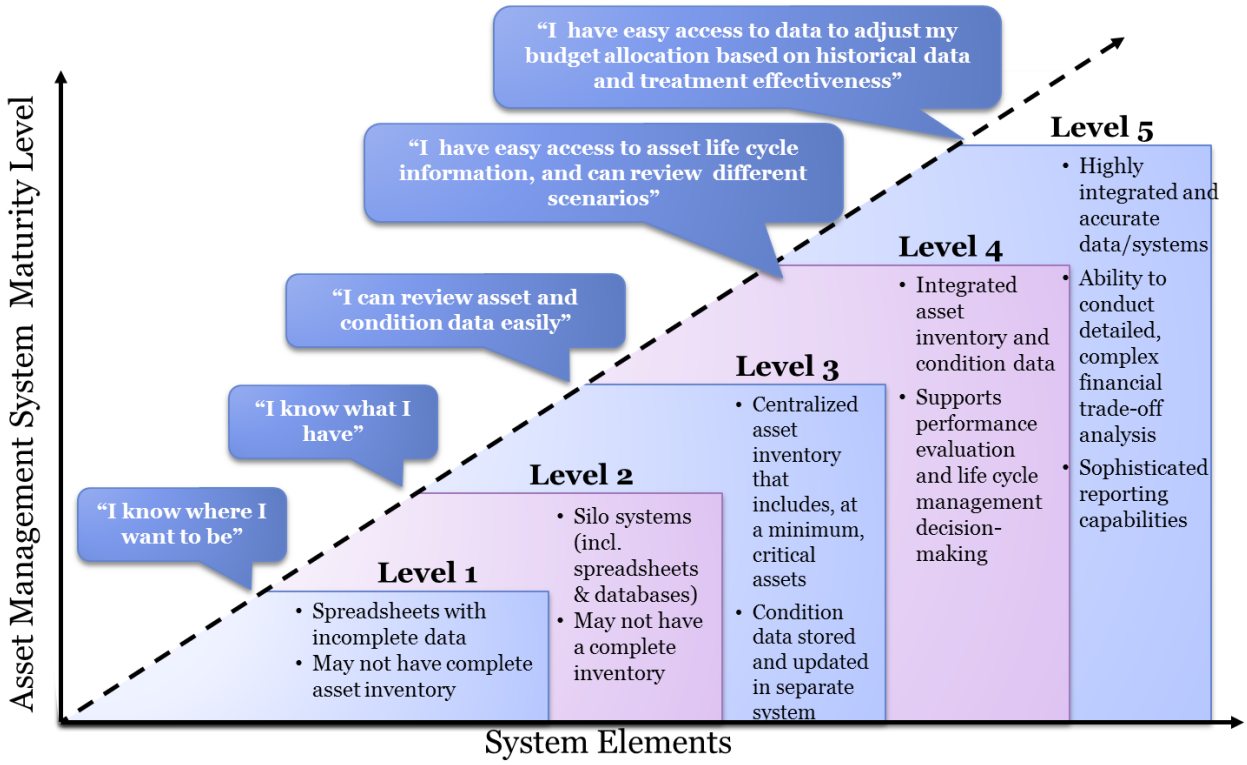
Numerous software systems and vendors provide enterprise asset management systems for DOTs. The capabilities of these systems vary and in many cases enterprise asset management systems are configured to meet the particular needs and requirements of a DOT. Enterprise asset management systems can serve as the foundation of an agency's asset management system.

Asset Management Maturity

All state DOTs have information systems of one type or another (with differing levels of automation) to support asset management and related activities. Most of these information systems provide capabilities to manage the life

cycle of pavements and bridges, and to some extent, ancillary assets. Most of these systems provide the capabilities to track the inventory and condition of assets and in some cases forecast asset condition and recommend treatments. More mature systems can also allow agencies to conduct trade-off analyses and help prioritize life cycle management activities. Different levels of asset management maturity are presented in Figure 5.

Figure 5 Asset Management System Maturity Levels



Approaches to Integrate Ancillary Assets into Enterprise Asset Management Systems

In most cases, information for ancillary assets is managed by different divisions – the divisions responsible for maintaining those assets. This information is typically stored in standalone databases or spreadsheets. Certain assets, such as overhead sign structures, signs and culverts, have received particular attention over the last few years due to either failures (overhead sign structures and culverts) or FHWA requirements (retroreflectivity standards for signs). For example, the FHWA developed a Culvert Management System (CMS) in 2001 that utilizes Microsoft Access. However, this voluntary culvert management system has not resulted in the use of CMS programs at a significant number of transportation agencies.

In general, when agencies decide to incorporate ancillary assets into enterprise asset management systems, the initial step is to upgrade to or procure a new enterprise asset management system that provides capabilities to manage pavements and bridges as well as other assets. Other steps that are critical to integrate ancillary assets into an enterprise asset management system involve an enterprise approach to asset management information that includes:

- Defining an asset classification/hierarchy to be used consistently through the agency and used in the enterprise asset management system
- Establishing the asset hierarchy and inventories of record for the hierarchy
- Collecting asset inventory data and entering this data into an enterprise asset management system or transitioning available asset inventory data to an enterprise asset management system linked to the inventory of record
- Collecting data on asset condition and entering data into an enterprise asset management system linked to the inventory of record

Once this information is entered, further information can be added to improve asset management such as:

- Determining future condition of assets based on research or past data – that is, adding the ability to forecast the future condition of assets
- Identifying lifecycle management activities and activity timing to most efficiently manage the assets

This information can help the agency prioritize treatments based on funding constraints. The data, when integrated with data on all other assets, can help the agency prioritize among different asset classes and conduct trade-off analysis.

CHAPTER 4: ANCILLARY ASSET CLASSIFICATION HIERARCHY

PURPOSE AND ROLE OF AN ANCILLARY ASSET CLASSIFICATION HIERARCHY

This chapter presents a generally agreed-upon asset classification hierarchy, which is required for an agency to implement ancillary asset management. It is a foundation for the inventory of record and one of the primary building blocks for life cycle management activities. The asset classification hierarchy presents assets at the highest level (asset class), followed by asset elements, and then sub-elements as applicable.

An agreed-upon hierarchy and definitions allow an agency to clearly identify the asset owners, establish the link to an asset's maintainable units, and provide a clear and common understanding that can be followed to prepare asset life cycle management activities and system requirements. This information is intended to serve as a guide for state DOTs instead of a prescriptive approach. Specific definitions as well as the asset classes may vary by agency depending on the definitions and the structure already in place at the agency.

Most agencies have an asset hierarchy in place, although it may be informal. Typically the hierarchy is driven by which divisions maintain the assets. For example, barrier systems (e.g. guardrails) may be a part of the traffic control group or the safety group; this can affect which asset class includes barrier systems. Furthermore, definitions for most asset classes, elements and sub-elements are present either in the agency's maintenance management systems, its ad-hoc asset maintenance system or in documentation prepared by the division responsible for the asset's maintenance.

The ancillary asset classification hierarchy presented in this chapter forms the starting point for an individual agency to establish an enterprise approach to ancillary asset management through an inventory of record that then forms an important component of an integrated enterprise asset management system as discussed Chapter 3. The ancillary asset management guidance presented in Chapter 5 is also organized around the classification hierarchy described below.

ANCILLARY ASSET CLASSIFICATION HIERARCHY

The starting point for an asset hierarchy for ancillary assets presented in this report organizes ancillary assets classes into the following categories:

- Structures (not bridges or otherwise in the NBI)
- Traffic Control & Management – Active Devices
- Traffic Control & Management – Passive Devices
- Drainage Systems and Environmental Mitigation Features
- Other Safety Features
- Roadside Features

Detailed definitions for the asset classes and sub-elements in this hierarchy follow in Table 2, which provides a broad, logical ancillary asset classification hierarchy that DOTs can use a basis to develop their own classification hierarchies. Although hierarchies in use vary from state to state, the asset classes, components, and sub-elements

defined in this chapter present a logical framework that is broadly consistent with the data architectures and inventories of record at many state DOTs. Additionally, several states have or are in the process of developing enterprise databases that contain information organized in a manner similar to the ancillary asset classes listed below.

Table 2 Ancillary Asset Classification Hierarchy

Asset Class	Asset Elements	Asset Sub-Elements (if Applicable)
Structures (not bridges or otherwise in the national bridge inventory)	Drainage structures	
	Overhead sign and signal structures	
	Retaining walls (Earth retaining structures)	
	Noise barriers	
	High mast light poles	
Traffic Control & Management – Active Devices	Signals	Signals, beacons, flashers, ramp meters
	ITS Equipment	Cameras, variable message signs, detection devices/sensors, highway advisory radios
	Network backbone	Hubs and nodes, fiber, cabinets, software
Traffic Control & Management – Passive Control Devices	Signs	Regulatory and warning signs Guide, service and attraction signs
	Barrier Systems	Guardrails, barrier walls, cable barriers, end treatments, impact attenuators
Drainage Systems and Environmental Mitigation Features	**Drain Inlets and Outlets**	Drains, drop inlets, catch basins, gutters
	Culverts (< 20 ft.)/Pipes	
	Ditches	Paved and unpaved ditches
	Environmental Mitigation Features (Storm Water Retention Systems)	
	Other Drains	Slotted drains
Other Safety Features	Lighting	
Roadside Features	**Sidewalks**	
	Curbs	ADA ramps

DEFINITIONS

This section presents the definitions for asset class, asset elements (components), and any sub-elements (where applicable).

ASSET CLASS: STRUCTURES

This asset class consists of any large structure that is not a bridge or otherwise in the national bridge inventory on or adjacent to the roadway. This includes:

Drainage structures

Large drainage structures, excluding culverts 20 feet or more in span length (measured in the direction of travel).

Overhead Sign and Signal Structures

This includes superstructures (generally steel) used to elevate overhead signs and signals

Retaining Walls (Earth Retaining Structures)

Structures that are constructed to support almost vertical (steeper than 70 degrees) or vertical slopes of earth masses are classified as retaining walls or earth retaining structures

Noise Barriers

A noise barrier is a physical obstruction or any other object that is constructed between the highway noise source and the noise sensitive receptor(s) to lower the noise level. This includes standalone noise walls, noise berms (earth or other material), and a combination berm/wall system.

High Mast Light Poles

High mast light poles are usually steel structures, up to 150ft high, placed in areas where widespread illumination is required, such as along interstates and at major highway interchanges

ASSET CLASS: TRAFFIC CONTROL & MANAGEMENT – ACTIVE DEVICES

This includes any equipment installed on and along the roadway and in control centers that is used for active traffic management. This includes devices used to actively regulate, warn, or guide traffic in order to move vehicles safely and efficiently by guiding traffic movement, controlling vehicle speeds, and warning drivers of potentially hazardous conditions. This includes:

Intelligent Transportation Systems (ITS) Equipment

This includes electronics, communications, or information processing equipment used singly or in combination to improve the efficiency or safety of a surface transportation system. This component/asset element includes the following sub-elements:

- **Cameras:** This primarily includes Closed-Circuit Television Cameras (CCTV) systems with pan, tilt, and zoom (PTZ) capabilities to monitor traffic conditions.

- **Variable Message Signs:** Programmatic devices that display messages composed of letters, symbols/graphics, or both. They are used to provide information about changing highway conditions in order to improve operations, reduce accidents and inform travelers. This includes variable speed signs that display different speed limits based on traffic patterns.
- **Detection Devices/Sensors:** Devices used to monitor vehicles (count, speed) along the roadway. This includes detection loops embedded in the roads and overhead monitoring equipment (e.g. toll monitors).
- **Highway Advisory Radios:** Radio transmitters placed at strategic locations along the roadway providing real-time information pertaining to traffic and road conditions. Drivers tune to specific frequencies to obtain this information.

Network Backbone

This includes the IT network that connects all the ITS equipment and supports the control and monitoring of all ITS assets. This includes the capability to communicate with the ITS devices remotely to control them (e.g. tilt cameras, review camera pictures, change message on variable message signs). This includes the fiber and cable network for data transfer, hubs and nodes that help with the data transfer, cabinets to store such equipment, and the software that helps with the monitoring and controlling.

Asset Class: Traffic Control & Management – Passive Control Devices

This asset class includes devices used to regulate, warn, or guide traffic. They may be placed on, over, or adjacent to the highway. The purpose of such devices is to move vehicles safely and efficiently by guiding traffic movement, controlling vehicle speeds, and warning drivers of potentially hazardous conditions. This includes:

Signs

Consists of all types of traffic signs, including regulatory and warning signs, guide and informational signs, regardless of the type of mounting (roadside posts, overhead sign structures, or attached to bridge structures). Signs include the following sub-elements:

- **Regulatory and warning signs:** Used to inform or call attention to road users of selected traffic laws or regulations or unexpected conditions on or adjacent to the roadway
- **Guide, service and attraction signs:** Used to inform road users of intersecting routes, to direct them to cities, towns, villages, or other important destinations, to identify nearby rivers and streams, parks, forests, and historical sites, and generally to give such information as will help them along their way in the most simple, direct manner possible

Barrier Systems

Longitudinal upright structures used to keep vehicles within the roadway and prevent vehicles from colliding with oncoming traffic or obstacles adjacent to the roadway. This includes the following sub-elements:

- **Guardrails:** Longitudinal barrier (typically metal, wood, or combination of both) used to separate the roadway and non-roadway within the right-of-way

- **Barrier Walls**: Longitudinal barriers used to separate opposing directions of traffic on a divided highway or to separate the roadway and non-roadway within the right-of-way
- **Cable Barriers:** Longitudinal barriers that use cable to separate roadway from surrounding.
- **End Treatments/Impact attenuators:** These mark the beginning/end of a guardrail or a barrier, and act primarily to bring an errant vehicle to a stop at a deceleration rate tolerable to the vehicle's occupants or to redirect the vehicle away from a fixed feature

Asset Class: Drainage Systems and Environmental Mitigation Features

This class includes different surface and subsurface assets with the primary purpose of moving storm water and other runoff from the surface assets to maintain mobility and safety. This includes culverts and pipes, ditches, drop inlets and catch basins, and other drains.

Drain Inlets and Outlets

This includes the following sub-elements:

- **Catch basins:** A receptacle at the entrance to a drain designed to keep out large or obstructive matter
- **Drop inlets:** An overfall structure in which water drops through a vertical riser connected to a discharge pipe/drain
- **Gutters:** Channel used to filter water to drain inlet

Culverts/Pipes

Culverts are drainage structures that carry water under the roadway or other obstacle (20 feet or less in span length, measured in the direction of travel). Pipes carry water within the drain system and may provide lateral or transverse drainage (may be described as cross and side drains).

Ditches

These are drainage structures that collect storm water surface runoff and transport it into a culvert or storm water sewer system. This includes the following sub-elements:

- **Paved ditches:** Ditches that are lined with either Portland cement concrete or asphalt concrete to prevent erosion and improve flow capabilities
- **Unpaved ditches:** Ditches that are lined with grass, sod, gravel, riprap, or soil

Environmental Mitigation Features (Storm Water Retention Systems)

These are features used to retain water for a period of time to control runoff and/or improve the quality (i.e. by reducing the concentration of nutrients, sediments, hazardous substances and other pollutants) of stormwater runoff.

Other Drains

These are the drains located under the roadway and along the edge of shoulder or curb. Slotted drains (drain covered by a slotted gate) are generally included in this category

Asset Class: Other Safety Features

This includes other transportation assets that help improve safety of roadway users. This includes:

Lighting

Lights used to illuminate roadway, parking lots, and other areas within the right-of-way (does not include high mast light poles).

Asset Class: Roadside Features

This class includes assets within the area between the outside edges of the shoulder and the right-of-way line. It is best defined as all non-paved areas within the right of way. This includes:

Sidewalks

Sidewalks are portion of a highway, road, or street intended for pedestrians

Curb

A curb is the transitional edge where a raised pavement, median, or shoulder meets an unraised roadway. ADA ramps that provide a tapering area for wheelchair access are included in this element.

CHAPTER 5: RECOMMENDED LIFE CYCLE MANAGEMENT BUSINESS PROCESSES FOR SELECTED ANCILLARY ASSETS

SUBSET OF ASSETS SELECTED FOR FURTHER FOCUS

One of the focus areas of the project was to update the life cycle management information from *NCHRP Synthesis 371* (Markow 2007), which focused on signals, lighting, signs, pavement markings, culverts, and sidewalks. An ongoing NCHRP Project, 07-21 "Asset Management Guidance for Traffic Control Devices, Barriers, and Lighting", addresses the following asset categories: Signs, Traffic Signals, Markings, Barrier systems, Lighting.

Given the emphasis of this in-progress NCHRP project, and scope limitations for this study, Parsons Brinckerhoff attempted to avoid overlap with this NCHRP project to the extent possible while focusing on assets that are most critical in terms of safety and mobility (as agreed upon by the project team and project panel).

The ancillary asset management guidance in this research focuses on the following asset elements (second-level bullets). The asset classes (first-level bullets) are presented here to allow the reader to tie the asset elements back to the asset classes presented in the hierarchy:

- Asset Class: Drainage systems and environmental mitigation features
  - Asset Element**: Culverts**
- Asset Class: Structures (not bridges or otherwise in the national bridge inventory)
  - Asset Element**: Drainage structures**
  - Asset Element**: Overhead sign and signal structures**
  - Asset Element**: High mast light poles**
- Asset Class: Traffic control and management – active devices
  - Asset Element**: ITS equipment**
  - Asset Element**: Network backbone**
- Asset Class: Roadside features
  - Asset Element**: Sidewalks/Curbs**

INTENT AND ORGANIZATION

This chapter provides guidance in the form of templates for each of the asset elements presented earlier. This guidance is based upon relevant literature, the team's expertise and prior experience, and the responses from the DOTs surveyed.

These templates are intended to serve as guidance to state DOTs as they move forward in efforts to improve ancillary asset life cycle management practices. In areas where best practices were not clearly defined in the literature or in the results of the state DOT surveys, the project team applied knowledge from its previous projects

and relevant literature to develop general guidance. As state-of-the-practice matures, these templates can be refined to describe generally accepted life cycle management business processes for each of the ancillary assets.

As discussed in Chapter 2, the recommended life cycle management business processes listed below can be divided into enterprise-level and asset specific-level sections. These templates provide the foundation for DOTs to develop asset management plans for the selected asset elements and are intended to serve as a starting point.

Enterprise-level

- **Inventory:** Describes linkage to enterprise-level inventory of record. Identifies those asset elements for which complete inventories are recommended and discusses the implications of maintaining less than 100% complete inventories for certain asset elements. In many cases limited resources and large quantities of assets present a challenge related to completing and maintaining 100% inventories. However, once a DOT has an EAMS in place, new asset elements should be added to the EAMS inventory during commissioning per a defined asset inventory process.
- **Interaction between Asset Classes:** Provides perspective on how a particular asset element and its associated asset class impact the performance of other asset classes and asset elements, namely an asset element's ability to provide safe, reliable, and cost effective transportation to the roadway user.
- **Relationship of Asset Class to Overall Safety, Mobility, and Asset Performance**: Discusses the risks to the performance of the entire roadway system arising from the performance of a specific asset element. For example, a failed culvert can result in the closure of the entire roadway. Describes an asset element's relationship to overall system performance and how DOTs manage any risks related to overall system performance.

Asset Specific-level

- **Inspection and Condition Assessment:** Provides recommendations related to the frequency of asset element inspection and the method of condition assessment.
- **Level of Service/Performance Metrics:** Discusses asset element condition ratings and level of service. Level of service or condition targets should balance cost, risk, and asset performance.
- **Lifecycle Management Plans and Practices:** Details recommendations related to recommended life cycle management activities, the potential application of life cycle cost analysis, and other implications for the development of long-term life cycle management plans and strategies.
- **Asset Prioritization:** Provides discussion related to what characteristics would drive prioritization for inspection, condition assessment, and life cycle management activities both within a particular asset element and between asset elements and asset classes
- **Decision Support:** Describes how asset element costs can be tracked and analyzed to inform future needs estimates and potentially estimate remaining service life.

In addition to the recommended life management processes listed above, the templates also contain the following sections for each ancillary asset element.

- **Asset Element-specific Considerations**: Discusses any unique implications for asset management for the selected asset elements based upon their purpose and intended functionality.

- **Additional References:** Describes sources of further information related to particular asset elements.

Asset Element: Culverts (<20 Ft)/Pipes

Culverts (<20 ft.)/Pipes – Asset Element of the *Drainage Systems and Environmental Mitigation Features* Asset Class

Asset Element-specific Considerations

In addition to providing essential drainage and hydraulic capacity for roadways, culverts can also provide crucial structural support for roadways, particularly larger culverts. Culverts are typically managed using systems similar to those used for pavements and bridges. In many cases, the size of culverts and pipes are the determining factor as to which division or unit within a DOT manages a particular culvert or pipe and which database or management system contains relevant culvert and pipe information.

In particular, it is important to note that culverts great than 20' in length (as measured along the roadway centerline) are part of the National Bridge Inventory (NBI) and thus typically managed by bridge units at DOTs. The threshold for defining larger culverts can vary, but many DOTs define culverts less than 20' but greater than 10' in length as larger culverts, which are typically the responsibility of bridge units. Smaller culverts and pipes are often the responsibility of roadway and/or maintenance units.

Enterprise-level

Inventory

Many DOTs maintain culvert inventories using data structures similar to those in place for bridges. Culvert inventories should be included in the enterprise asset management system inventory as the inventory of record and should contain essential data items including location, condition, and age. Additional inventory data items may include material type, deterioration rate, expected remaining service life, etc. The type of culvert database used at agencies to store inventory information varies and includes: proprietary systems, PONTIS, FHWA-developed Culvert Management System (CMS), and other structures/maintenance databases.

Since culverts greater than 20' in length are in the NBI these have a 100% inventory. For larger culverts (> 10'), identified higher-risk culverts, and culverts on heavily-trafficked roadways, a 100% inventory is recommended. Inventories for smaller and lower-risk culverts can be developed over time as more culverts are inspected in conjunction with other roadway maintenance work. Although agencies may not maintain complete inventories of smaller culverts, these culverts tend to clog more easily than larger culverts and are also typically made of materials that deteriorate more rapidly. For this reason, efforts should be made to establish inventories for small culverts where these inventories do not already exist.

Interaction between Asset Classes

In many cases, culverts can affect the structural integrity of roadway segments and thus the performance of the entire roadway, and other roadway assets such as pavements. A risk-based approach towards culvert inspection,

condition assessment, and maintenance can mitigate the potential for culvert failures to adversely impact the performance of other roadway assets.

Relationship with Overall Safety, Mobility, Asset Performance

Culvert failures can affect other roadway assets, resulting in closure of roadway segments. Furthermore, culvert blockages can limit and/or impede functionality of the roadway system by impacting drainage capacity.

ASSET SPECIFIC-LEVEL

Inspection and Condition Assessment

There is normally variation in frequency of culvert inspection cycles with culvert size being a driving factor. Typically larger culverts are inspected biennially in line with NBI inspection cycles whereas smaller culverts may be inspected once every four years. In addition, some agencies identify "higher-risk" culverts or culverts in poor condition and may inspect these culverts annually or with greater frequency.

Similar to bridge inspections, culvert inspections are typically visual inspections, particularly for larger culverts. Photo logging capability can be a valuable tool to support culvert inspection and condition assessment. Robotic devices with cameras may also be used to inspect smaller culverts that cannot be adequately inspected with visual inspections. Some agencies use customized culvert inspection standards to assess and rate condition (Wyant 2002).

Level of Service/Performance Metrics

Typically culvert performance is monitored using condition ratings similar to those used for bridges, with a certain threshold indicating that a culvert is in unacceptable condition, as specified by FHWA condition rating guidelines (FHWA 1995; Arnoult 1986). For estimated service life of various types of box and pipe culverts by material type see *NCHRP Synthesis 303* (Wyant 2002).

Life Cycle Management Plans and Practices

To manage culverts many DOTs use data structures and condition ratings similar to those used for bridges. This presents the opportunity to use the techniques and decision trees similar to those used in bridge management systems for culvert management systems. This however would require that agencies model culvert performance and utilize culvert management systems that identify treatment appropriate life cycle management activities and their timings.

Asset Prioritization

If an existing culvert risk management approach does not identify higher-risk culverts, DOTs can define criteria, e.g., culvert condition rating, roadway traffic volume, roadway redundancy, percentage trucks, etc. to assess culvert risk. For example, a culvert on a roadway that provides the only access point into or out of a community could be considered higher-risk and identified for more frequent inspection. In addition to prioritizing higher-risk culverts for more frequent inspection, these culverts can also be prioritized for replacement and rehabilitation.

Decision Support

Agencies can use culvert condition data and historic maintenance data to develop needs estimates. This information can also be used to estimate remaining service life and develop risk-based inspection and replacement

programs. Agencies can track the performance of different material types in various environmental conditions to inform future decisions regarding culvert material type in certain locations (Markow 2007).

Additional References

In 2001 the FHWA developed a Culvert Management System (CMS) that utilizes Microsoft Access. However, this voluntary culvert management system has not resulted in the use of CMS programs at many transportation agencies. One benefit of the FHWA-developed CMS is its flexibility; unlike many bridge management programs, it does not require mandatory inputs of large amounts of data items and can be customized by the user (Davidson & Grimes 2006).

FHWA acknowledged that although many DOTs realized the importance of a CMS, there is a lack of training materials and guidance on culvert inspection. In order to address this, the FHWA plans to develop a new CMS and inspection training materials (FHWA 2007). It should be noted that although the NBI contains culverts greater than 20' in length, some DOTs also include culverts greater than 10' in the NBI.

For additional information on physical measurements and condition rating scales that agencies use to assess culvert condition see *NCHRP Synthesis 303* (Wyant 2002). For further detail on culvert performance and service life based on material type see *NCHRP Synthesis 371* (Markow 2007) and *NCHRP Synthesis 254* (Gabriel & Moran 1998).

Asset Elements: Drain Inlets and Outlets, Ditches, Storm Water Retention Systems, and Other Drains

Asset Elements of the *Drainage Systems and Environmental Mitigation Features* Asset Class

Asset Element-specific Considerations

Drainage infrastructure asset elements, including ditches, inlets and outlets, and storm water retention systems provide roadways with hydraulic capacity. Drain inlets and outlets include the following asset sub-elements: catch basins, drop inlets, and gutters. Ditches include both paved and unpaved ditches. Environmental mitigation features, also known as storm water retention systems, retain water for a period of time, typically to improve water quality. Other drains include slotted drains and drains located under the roadway and along the edge of a shoulder or curb. The primary purpose of these drainage infrastructure assets is to move storm water and other runoff from the surface of roadway assets. Incorporating maintainability into drainage infrastructure asset element design is an important consideration so that blockages are limited.

Environmental mitigation features also serve to improve water quality and thus can be subject to Environmental Protection Agency (EPA) regulations. Given the large quantity of drainage infrastructure assets and a general lack of management systems for these assets at DOTs, there can be challenges associated with the maintenance and operations of drainage infrastructure assets, which may be managed across multiple units at DOTs, including bridge and maintenance units. In addition, drainage infrastructure assets related to storm water management often fall under the jurisdiction of environmental or natural resource agencies.

ENTERPRISE-LEVEL

Inventory

Since the aforementioned drainage infrastructure asset elements may be managed across multiple units at many DOTs, and thus inventories may reside in multiple systems/databases, it is important to incorporate drainage infrastructure asset inventories into the enterprise asset management system inventory to establish an inventory of record. For example, many DOTs incorporate certain drainage infrastructure asset elements into existing culvert databases and maintain standalone databases for other drainage infrastructure asset elements. Given the large quantity and variety of drainage infrastructure asset elements, DOTs rarely maintain 100% inventories of all drainage infrastructure asset elements. Inventories of drainage infrastructure asset elements should contain basic data items including location, condition, and age. Inventories may also include additional data items such as material type, deterioration rates and expected remaining service life.

Depending on the type of Enterprise Asset Management System (EAMS) in place at a DOT, drainage infrastructure asset elements not already contained as part of the EAMS inventory can be added to the inventory during regularly scheduled roadway maintenance to reduce inventory costs. Alternatively, DOTs can use outside vendors and contractors to assist in developing more complete inventories of drainage infrastructure asset elements.

Interaction between Asset Classes

Drainage infrastructure asset elements can impact pavement condition, especially those asset elements located underneath the roadway surface. In particular, the hydraulic capacity of drainage asset elements and drainage infrastructure conditions should be considered in pavement projects. For this reason, projects intended to improve pavement condition can also serve as a means to improve drainage infrastructure asset elements.

Relationship with Overall Safety, Mobility, Asset Performance

Insufficient hydraulic capacity, and failure to consider the need for increased hydraulic capacity during roadway improvement projects, can lead to poor roadway performance as a result of insufficient drainage capacity. In addition, failure to ensure that drainage infrastructure asset elements remain clear of blockages can lead to standing water on roadway surfaces.

ASSET SPECIFIC-LEVEL

Inspection and Condition Assessment

Drainage infrastructure asset elements are typically inspected during regularly scheduled roadway maintenance activities or as part of annual measurement and reporting of maintenance Level of Service (LOS), also known as Maintenance Quality Assurance (MQA) among states with MQA programs. Drainage infrastructure asset elements are typically inspected visually to assess whether a particular asset element is functioning as designed and if there are any blockages impeding drainage. However, given the wide-range of drainage asset elements, inspection procedures beyond visual inspection, e.g., video camera or remote controlled video camera inspections, can be used for different asset elements.

Typically DOTs conduct LOS surveys to determine MQA for drainage infrastructure asset elements on an annual basis. For drainage asset elements, these LOS surveys need not be performed on the entirety of drainage infrastructure asset elements in the state but rather on a statistical sample. The methods used to determine what

constitutes a statistically significant sample of drainage infrastructure assets vary; see *NCHRP Report 677* (Dye Management Group et al. 2010) for further detail regarding statistical sampling methods.

It should be noted that there are specific inspection requirements associated with Municipal Separate Storm Sewer Systems (MS4s) that require EPA permits or permits from a state's regulatory authority where responsibility is delegated to the state by the EPA; the minimum inspection frequency is detailed in the permit.

Level of Service/Performance Metrics

For the identified drainage infrastructure asset elements, level of service and performance are typically measured using MQA procedures. The metrics used to assess the performance of drainage infrastructure asset elements include the percentage of drainage infrastructure asset elements that are damaged and the percentage of drainage infrastructure asset elements more than 25% blocked. LOS thresholds ranging from A to F, with F indicating the worst performance, are defined as follows based upon the percentage of drainage infrastructure asset elements that are damaged or more than 25% blocked (Dye Management Group et al. 2010):

- A: 0 to 4.9%
- B: 5 to 9.9%
- C: 10.0 to 14.9%
- D: 15.0 to 19.9%
- F: ≥ 20%

Life Cycle Management Plans and Practices

In many cases, DOTs identify drainage infrastructure asset elements for repair or replacement based on condition assessments and coordinate associated repairs and replacements with pavement or bridge projects. In order to maintain drainage infrastructure asset element capacity, regular sediment removal is required. For certain drainage infrastructure asset element rehabilitation or reconstruction projects additional hydraulic capacity is required and thus modifications and/or enhancements to drainage infrastructure asset elements may also be required.

Asset Prioritization

Most DOTs do not have a formalized process to prioritize life cycle management activities and investments for drainage infrastructure asset elements. In many cases, an ad-hoc approach is used to prioritize drainage infrastructure assets when a blockage or damage is discovered. For DOTs with more complete inventories of drainage infrastructure asset elements, condition and/or replacement value can be used to prioritize.

Decision Support

Given the wide range of drainage infrastructure asset elements, and the general lack of complete inventories for drainage infrastructure asset elements, accurately tracking costs associated with the maintenance of drainage infrastructure asset elements can be a challenge. Roadway construction and maintenance projects typically include line item costs for drainage infrastructure asset elements; these costs can be used to inform future repair and replacement cost estimates.

Additional References

For further information on Maintenance Quality Assurance (MQA) programs at DOTs see *NCHRP Report 677* (Dye Management Group et al. 2010). See EPA guidance and documentation related to transportation-specific stormwater needs for Municipal Separate Sewer Systems (MS4s) permits (EPA 2010).

Asset Element: Overhead Sign and Signal Structures

Asset Element of the *Structures* Asset Class

Asset Element-specific Considerations

Overhead sign and signal structures support elevated, overhead signs and signals. The signs and signals supported by these structures are critical components of the safety and operations of the roadway network. Overhead signs provide warning, regulatory, and guidance information to roadway users. Overhead sign and signal structures that support variable message signs, signals, and other ITS equipment provide safety and guidance to roadway users and can improve system reliability.

Overhead sign and signal structures represent relatively high value asset elements, particularly when considering that some overhead sign structures support variable message signs. In addition, the failure of overhead sign and signal structures poses a safety risk and can also reduce mobility. For this reason, many agencies have established or are in the process of developing formal management systems for overhead sign and signal structures.

Enterprise-level

Inventory

Many DOTs maintain overhead sign and signal structure inventories in standalone structures inventory databases since overhead sign and signal structure inventories require the collection of significant amounts of data. In some cases these inventories are distributed between regions and may have different data definitions and asset information. DOTs with Enterprise Asset Management Systems (EAMS) in place should include overhead sign and signal structure inventories in the EAMS as the inventory of record. These overhead sign and signal structure inventories should contain essential data items including location, condition, and age. Inventories may also contain additional data items such as material type, deterioration rate, expected remaining service life, etc.

Although DOTs may not maintain 100% inventories of overhead sign and signal structures, it is recommended that DOTs incorporate overhead sign and signal structures into their inventories of record over time. Particular attention should be given to overhead sign structures that support regulatory and warning signs, which are subject to FHWA retroreflectivity standards. Although these standards do not require that all regulatory and warning signs meet retroreflectivity standards at all times, agencies must have a method in place to identify and replace noncompliant regulatory and warning signs (FHWA 2012a). One approach to achieving compliance could be establishing a statistical sampling method, which would not require a complete inventory, to identify noncompliant signs.

Interaction between Asset Classes

Overhead sign and signal structures in poor condition pose a risk to the safe function of the highway system since failed structures can close crucial links in the roadway system. In addition, when supports for overhead sign and signal structures are placed on or adjacent to roadways or sidewalks, designs should consider the potential impact of vehicular collisions on the sign support structures. Certain overhead sign structures may support variable message signs, which are important ITS equipment asset elements; the functionality of these overhead sign structures is essential to the functionality of the variable message signs.

Relationship with Overall Safety, Mobility, Asset Performance

Overhead sign and signal structures are a critical feature of the roadway system since these structures support the signs and signals that provide guidance to roadway users. Furthermore, overhead sign and signal structures support variable message signs, which can improve traffic flow and safety.

ASSET SPECIFIC-LEVEL

Inspection and Condition Assessment

To assess the condition of overhead sign and signal structures, condition rating scales similar to bridges and/or culverts are often used. DOTs that do not already have inspection and condition rating procedures in place for overhead sign and signal structures should consult the FHWA *Guidelines for the Installation and Repair of Structural Supports of Highway Signs, Luminaries, and Traffic Signals* (see Garlich & Thorkildsen 2005). Since most overhead sign and signal structures are not as complex as bridges, more simplified condition rating scales, e.g., a rating scale of 1 to 5, are typically used.

Overhead sign and signal structures typically require a thorough visual inspection of components, including the base plate and anchor bolts. Inspection procedures differ by the type of support structure but need to go beyond basic visual inspection to include Non Destructive Testing (NDT) techniques, which are important tools for inspecting ancillary structures (Garlich & Thorkildsen 2005), to identify potential structural deficiencies. The required inspection frequency of overhead sign and signal structures varies and depends on several factors including material type, e.g., aluminum shows increased fatigue deficiencies, and redundancy issues.

Cantilever and non-redundant designs should be inspected every two years whereas typical sign bridges, i.e., two tower/two or four post structures, should be inspected every four years. Where resource constraints prevent the inspection of all overhead sign and signal structures, a statistical sample, i.e., 10% of assets, can be used to inform inspection programs. Furthermore, after high-wind weather events, i.e., severe storms, hurricanes, or tornadoes, overhead sign and signal structures in impacted areas should be prioritized for inspection.

Level of Service/Performance Metrics

To monitor and measure the level of service and performance of overhead sign and signal structures, typically current performance versus originally intended function is used, i.e., are the overhead sign and signal support structures, and its components, in acceptable condition. *NCHRP Synthesis 371* estimates the service life for steel and aluminum overhead sign and signal structures, with a median service life of approximately 31 years and 27 years respectively (Markow 2007).

Life Cycle Management Plans and Practices

The age of overhead sign and signal structures along with condition rating information are used to develop plans for replacement. DOTs typically perform regular maintenance, such as tightening loose anchor bolts and other loose hardware, during regularly scheduled overhead sign and signal structure inspections. Potential damages related to collisions and high-wind weather events should also be considered. When DOTs add additional signs to existing overhead sign and signal support structures the carrying capacity of the structures should be evaluated.

Asset Prioritization

Overhead sign and signal structures with older designs and materials should be prioritized for inspection, especially if statistical samples of inspections, i.e., 10%, indicate more rapid deterioration for older designs and materials. In addition, cantilevered sign structures and sign structures supporting variable message signs should be prioritized for inspection. After high-wind weather events, overhead sign and signal structures in impacted areas should be prioritized for inspection.

Decision Support

DOTs can estimate the remaining service life of overhead sign and signal structures based on the date of erection and current condition ratings. This information can also be used to develop needs estimates for overhead sign and signal structure repair and replacement. Tracking historical maintenance costs, e.g., base plate anchor bolt repair and tightening, can inform estimates of future maintenance needs. In addition, costs related to damages to overhead sign and signal structures from collisions and high-wind weather events should be factored into budgeting.

Additional References

FHWA has developed guidelines for structural supports of highway signs, luminaries, and traffic signals (see Garlich & Thorkildsen 2005). For additional information on estimated service life of overhead sign and signal structures see *NCHRP Synthesis 371* (Markow 2007).

Asset Element: High Mast Light Poles

Asset Element of the *Structures* Asset Class

Asset Element-specific Considerations

Along with other types of roadway illumination, the lighting provided by high mast poles can provide a proven improvement to nighttime driving conditions and result in improved safety by reducing the number of crashes. Although agencies do not typically maintain a large number of high mast light poles, these assets pose unique life cycle management challenges and their failure can impact the safety and mobility of the roadway system.

In particular, the height of high mast light poles presents a challenge in terms of the manner in which many high mast light poles can be inspected, i.e., height that extends beyond the limits of a bucket truck. For example, to observe the extent of cracking on high mast light poles some sort of remotely controlled device can scale the pole or a system that utilizes the existing winch, cable and lighting ring hardware within the pole can be used (see Sheth

& Montie 2005). These sorts of unique considerations for high mast light poles can be used to estimate life cycle cost and inform design and procurement strategies.

ENTERPRISE-LEVEL

Inventory

Many DOTs maintain inventories for high mast light poles in the same databases/systems used to inventory overhead sign and signal structures, which are typically standalone databases/systems. High mast light pole inventory information should be stored in the enterprise asset management system inventory as the inventory of record. This inventory should contain basic asset information data items including location, condition, and age. Additional inventory data items may include material type and expected remaining service life. It is recommended that DOTs maintain 100% inventories of high mast light poles since these are in highly-trafficked areas and provide safety benefits.

Interaction between Asset Classes

Similar to overhead sign and signal structures, high mast light poles in poor condition pose a significant risk to the safe function of the highway system. High mast light pole failures can result in closures of crucial links in the highway system.

Relationship with Overall Safety, Mobility, Asset Performance

High mast light poles provide illumination that improves nighttime roadway performance, which can improve safety at lit interchanges and interchanges.

ASSET SPECIFIC-LEVEL

Inspection and Condition Assessment

Due to their height, it can be challenging to inspect high mast poles. Visual inspections can be performed using binoculars or telescopes, such as a shooter's spotting telescope. However, identifying structural deficiencies with binoculars or telescopes can be challenge. Remotely operated inspection devices, which contain video cameras and additional inspection equipment, can be used (Sheth & Montie 2005).

Similar to overhead sign and signal structures, non-destructive testing techniques can also be used to inspect the base plates and anchor rods of high mast light poles. High mast light poles should be inspected at least every four to five years. Anchor bolts at the base of high mast light poles have been known to loosen over time and may require more frequent inspection (Garlich & Thorkildsen 2005).

Level of Service/Performance Metrics

The level of service and performance of high mast light poles is typically measured in terms of a simple condition rating scale that compares current performance against originally intended function (Garlich & Thorkildsen 2005).Survey results from *NCHRP Synthesis 371* indicate a median service life for high mast light poles, i.e., high mast towers or structural supports, of 30 years with a minimum of 10 years and a maximum of 50 years. High-pressure sodium vapor lamps are commonly used in high mast light poles and have a median estimated service life of 4 years, which often aligns with high mast light pole inspection schedules (Markow 2007).

Life Cycle Management Plans and Practices

DOTs can track maintenance activities associated with high mast light poles and forecast future life cycle management activities, i.e., anchor bolt tightening, based upon historic data. In addition, life cycle cost analysis can determine if repair or replacement is warranted for high mast light poles. DOTs should also account for the need to replace lamps in high mast light poles; service life estimates for specific types of lamps can be found in *NCHRP Synthesis 371* (Markow 2007).

Asset Prioritization

After high-wind weather events high mast light poles in affected areas can be prioritized for inspection. In addition, high mast light poles in areas with known nighttime safety issues should be prioritized for inspection.

Decision Support

Maintenance costs, e.g., base plate repairs, anchor bolt tightening, lamp replacement, can be tracked and historical data be used to estimate future maintenance needs. DOTs can estimate the remaining service life of high mast light poles using installation date and current condition information.

Additional References

The aforementioned FHWA guidelines for overhead sign and signal structures also discuss high mast light poles (Garlich & Thorkildsen 2005). Details regarding remotely-operated high mast light pole inspection devices can be found in a Virginia Transportation Research Council (Sheth & Montie 2005) report. For further information on fatigue cracking in galvanized high mast light poles, ultrasonic testing techniques, and guidance for the identification of critical pole locations and configurations please see a report performed for Texas DOT (Goyal et al. 2012).

Asset Element: ITS Equipment

Asset Element of the *Traffic Control & Management – Active Devices* Asset Class

Asset Element-specific Considerations

The asset sub-elements included in the ITS equipment asset element are: cameras (primarily Closed-Circuit Television Cameras –CCTV), variable message signs, detection sensors/devices, and highway advisory radios. These asset sub-elements comprise the components of Intelligent Transportation Systems (ITS) which are designed to actively regulate, warn, or guide roadway users. ITS, and their individual asset elements and sub-elements, have become increasingly critical components of the operations of many DOTs.

ITS asset elements and sub-elements are diverse and technologically-intensive, presenting unique challenges in terms of the life cycle management activities for ITS equipment. In comparison to other roadway assets, such as pavements, bridges, and other structures, e.g., high mast light poles, with relatively long expected design lives, ITS equipment asset sub-elements have relatively short, i.e., 10 to 15 years or less , expected design lives. In many cases, ITS equipment asset sub-elements are used until they become obsolete or are no longer functioning as originally intended. In some cases, ITS asset elements and sub-elements are managed in separate ITS management systems or databases. In addition, DOTs often use performance-based, i.e., uptime, contract maintenance for ITS asset elements and sub-elements.

ENTERPRISE-LEVEL

Inventory

Given their importance to safe, efficient roadway operations, and the relatively small quantity of ITS equipment asset sub-elements DOTs own and maintain, the inventory of these asset sub-elements should be complete, i.e., 100%. ITS equipment asset sub-element inventories may be maintained in specialized ITS management systems. DOTs with Enterprise Asset Management Systems (EAMS) should link the ITS equipment inventory to the EAMS if using a specialized ITS management system. Those DOTs that do not use specialized ITS management systems but store the ITS equipment inventory in a standalone database/system should integrate this ITS equipment inventory into the EAMS inventory as the inventory of record. The inventory of ITS equipment asset sub-elements should contain basic data items including location, condition, and age. Inventories may also include additional data items such as material type and expected remaining service life.

Interaction between Asset Classes

Certain ITS equipment asset sub-elements, such as variable message signs and CCTVs, require functionality of overhead sign structures and high mast light poles. These ITS equipment asset sub-elements are a critical part of an overall ITS system and many asset sub-elements interface with the network backbone.

Relationship with Overall Safety, Mobility, and Asset Performance

These ITS equipment asset sub-elements are an increasingly critical component of transportation system operations. This equipment and associated ITS systems can improve network performance and user awareness and safety through the communication of real-time travel information to the public. Benefits of ITS equipment and ITS systems to travelers can be quantified in terms of dollar value of travel time savings. In addition, ITS systems can be used for traffic reporting and forecasting and speed enforcement.

ASSET SPECIFIC-LEVEL

Inspection and Condition Assessment

The asset sub-elements cameras, variable message signs, and detection sensors/devices should be inspected at routinely scheduled intervals. Given the relatively short expected service lives, i.e., 10 to 15 years or less, of ITS equipment asset sub-elements, during a visual inspection, physical condition can simply be assessed in terms of whether an asset sub-element is functioning as originally intended. For many ITS equipment sub-elements, functionality can be monitored in real-time, e.g., whether or not a CCTV is providing a feed.

Level of Service/Performance Metrics

Typically the performance metric used to assess ITS equipment asset sub-elements is whether or not the asset sub-elements are functioning as originally intended and are ready and available for use. For the ITS equipment asset sub-elements CCTVs and detection sensors/devices, functionality can be determined in real-time. Although the functionality of variable message signs may not be available in real time, it is likely that roadway users or DOT personnel would report malfunctions of variable message signs.

The service life of the asset sub-elements is affected by many factors, including environmental conditions, but sample service life information for cameras, variable message signs, detection sensors/devices, and highway advisory radios is shown in Table 3 (Vick & Sumner 2002).

Table 3 Sample Service Life for ITS Equipment Asset Sub-elements

Asset Sub-element	Sample Estimated Service Life (years)
Cameras (CCTVs)	10
Variable Message Signs	20
Detection Sensors/Devices	5 (for inductive loop sensors) 10 (for remote microwave sensors)
Highway Advisory Radio	20

Life cycle Management Plans and Practices

The ITS equipment asset sub-elements (cameras, variable message signs, and detection devices/sensors) require routine maintenance. Some DOTs follow maintenance standards set forth in ITS maintenance manuals, which can recommend frequencies for maintenance and also detail maintenance activities. For example, the Pennsylvania DOT recommends preventive maintenance activities for cameras, variable message signs, and detection devices/sensors at least twice per year (PennDOT 2011).

Given their relatively short expected service lives, DOTs should develop life cycle management plans for these ITS equipment asset sub-elements that consider replacement costs and schedules; ITS maintenance standards and manuals can inform the development of these life cycle management plans. Furthermore, ITS equipment sub-element performance in comparison to manufacturer specifications and warranties should be considered in future procurements. DOTs that outsource the inspection and maintenance of these ITS equipment asset sub-elements should structure contracts such that DOTs still maintains access to asset inventory and condition data.

Asset Prioritization

DOTs typically do not maintain significant quantities of these ITS equipment asset sub-elements. Additionally, given that most of these asset sub-elements are typically located in high-traffic volume areas, nearly all of the ITS equipment asset sub-elements cameras, variable message signs, and detection devices/sensors should be prioritized for inspection, routine maintenance, and scheduled for replacement and the end of their service lives. Those assets in the most heavily-trafficked areas should be prioritized ahead of others.

Decision Support

DOTs should track historic maintenance costs and ITS equipment asset sub-element performance to assess the suitability of ITS equipment asset sub-elements in local environmental conditions. To better inform maintenance programs and future ITS equipment asset sub-element specifications for replacement, DOTs should track actual service life and compare it to manufacturer service life estimates.

Additional References:

For additional information on ITS equipment sub-element maintenance see *Guidelines for Transportation Management Systems Maintenance Concept and Plans* (Vick & Sumner 2002) and PennDOT's *Intelligent Transportation Systems Maintenance Standards* (PennDOT 2011). In addition, the U.S. DOT's ITS Joint Program Office (JPO) maintains four related web-based databases, known as the ITS "Knowledge Resources" (KRs), that contain over 15 years of summaries of benefits, costs, lessons learned, and deployment status of specific ITS

implementations. These resources can be accessed at www.itskrs.its.dot.gov. The most recent report based on the KRs, released in 2011, was based on 1,148 summaries of ITS benefits, costs, and lessons learned (Bunch et al. 2011).

In an example of the state-of-the-practice, the Florida DOT analyzed three potential commercial-off-the-shelf (COTS) ITS management software systems, OSPInSight, FiberTrak, and Fiber Management Tool for ITS (FMT-ITS). Ultimately FDOT chose FMT-ITS (now NexusWorks) since its best met the Department's needs (see Fries et al. 2013 for more information on FDOT's experience). For further information on the importance of ITS in asset management systems see this Austroads position paper (Martin 2002).

Asset Element: Network Backbone

Asset Element of the *Traffic Control & Management – Active Devices* Asset Class

Asset Element-specific Considerations

The network backbone consists of the Information Technology (IT) network that connects all of the ITS equipment and supports the ITS equipment asset sub-elements that actively warn, guide, and inform roadway users. Asset sub-elements of the network backbone include: hubs and nodes, fiber, cabinets, and software. The fiber allows for data transfer, hubs and nodes assist with this data transfer, cabinets store certain asset sub-elements, and software helps monitor and control the IT network.

Adequate functionality of the network backbone asset sub-elements is required for the functionality of ITS equipment asset sub-elements. Much like the ITS equipment asset sub-elements, certain network backbone asset sub-elements have relatively short design lives, with the exception of fiber (although fiber can be severed during construction activities) and cabinets.

Enterprise-level

Inventory

Similar to the ITS equipment asset sub-elements, complete or 100% inventories should be maintained for network backbone asset sub-elements. DOTs typically do not maintain significant quantities of network backbone asset sub-elements. In addition, the functionality of network backbone asset sub-elements is critical to the functionality of the ITS equipment sub-elements and thus overall ITS operations. Network backbone asset sub-elements may be maintained in their own ITS management systems or in standalone databases/systems.

DOTs with Enterprise Asset Management Systems (EAMS) should include network backbone asset sub-element inventories in the EAMS inventory as the inventory of record. DOTs that use specialized ITS management systems for network backbone asset sub-elements should link the inventory to the EAMS. The inventory of network backbone asset sub-elements should contain basic data items including location, condition, and age. Additional inventory data items may include material type and expected remaining service life.

Interaction between Asset Classes

Network backbone elements underpin the functionality of ITS equipment since asset sub-elements such as fiber and hubs and nodes are used by ITS equipment asset sub-elements. Along with ITS equipment asset sub-elements, network backbone asset sub-elements are critical to ITS operations.

Relationship with Overall Safety, Mobility, Asset Performance

Since functioning network backbone asset sub-elements are essential to the functionality of ITS equipment asset sub-elements, network backbone asset sub-elements provide the foundation for ITS operations. Network backbone asset sub-elements can help improve transportation system performance by increasing user awareness and safety through the communication of real-time travel information to the public.

ASSET SPECIFIC-LEVEL

Inspection and Condition Assessment

The functionality of hubs and nodes can be assessed using automatic monitoring tools, which can indicate status in real-time. Those hubs and nodes not functioning as originally intended can be inspected during regularly scheduled maintenance. Fiber typically cannot be inspected since the majority of the fiber network is below the roadway surface. Cabinets should be inspected for damage during the regularly scheduled maintenance required for the asset sub-elements house within the cabinet. Software is not physically inspected but rather can be assessed for suitability and the potential for upgrades.

Level of Service/Performance Metrics

The performance metric typically used to assess network backbone asset sub-elements is whether or not the asset sub-elements are functioning as originally intended and are ready and available for use. For the network backbone asset sub-elements fiber, hubs and nodes, and software functionality can be determined in real-time. For the asset sub-element cabinets, performance is typically assessed based on whether or not the asset sub-element is functioning as originally intended, i.e., providing adequate protection for the equipment housed in the cabinet.

Life cycle Management Plans and Practices

The network backbone asset sub-elements hubs and nodes, cabinets, and software require routine maintenance. Specific maintenance requirements and frequencies can vary from one asset sub-element to another and are typically detailed in manufacturer specifications. These asset sub-elements may also be under warranty for an initial time period. Hubs and nodes require routine maintenance. Software typically requires maintenance in the form of upgrades. Although fiber does not require routine maintenance, DOTs should plan to replace fiber that is severed during construction activities.

Similar to ITS equipment, DOTs should consider the 10 to 20 year (Vick & Sumner 2002) expected service life of certain network backbone asset sub-elements (hubs and nodes and cabinets) when developing life cycle management plans for these asset sub-elements. These life cycle management plans should consider replacement costs and schedules and also account for the environmental conditions network backbone sub-elements are exposed to. In addition, DOTs should consider costs associated with required upgrades for the asset sub-element software. DOTs that outsource the inspection and maintenance of network backbone asset sub-elements should structure contracts such that DOTs still maintains access to asset inventory and condition data.

Asset Prioritization

Since DOTs typically do not maintain significant quantities of network backbone asset sub-elements, and given that most of these asset sub-elements are typically located in high-traffic volume areas, essentially all of the network backbone asset sub-elements should be prioritized for inspection, routine maintenance, and scheduled for replacement and the end of their service lives. Those assets in the most heavily-trafficked areas should be prioritized ahead of others.

Decision Support

Historic maintenance costs associated with network backbone asset sub-elements should be tracked and in addition to informing future needs estimates, can also be used to assess the suitability of network backbone asset sub-elements in local environmental conditions. In addition, DOTs should track actual service life and compare it to manufacturer service life estimates for network backbone asset sub-elements to better inform maintenance programs and future network backbone asset sub-element specifications for replacement.

Additional References

Similar to ITS equipment, additional information on network backbone asset sub-element maintenance can be found in *Guidelines for Transportation Management Systems Maintenance Concept and Plans* (Vick & Sumner 2002) and PennDOT's *Intelligent Transportation Systems Maintenance Standards* (PennDOT 2011) for an example of a State's ITS maintenance manual. Along with data on ITS equipment asset sub-elements, the U.S. DOT's ITS JPO ITS "Knowledge Resources", also contains information on network backbone asset sub-elements. These resources can be accessed at www.itskrs.its.dot.gov. The most recent report based on the KRs, was released in 2011 (see Bunch et al. 2011).

Like the ITS equipment state-of-the-practice example, FDOT's procurement of FMT-ITS (now NexusWorks) as it ITS management system software provides an example of specialized ITS management software, which was adapted from the telecommunications industry. In this instance, FDOT's Facility Management System (ITSFM) is a GIS-based web application that provides a model of fiber network facilities and connected devices, ITS devices, and the electrical system powering the ITS devices (see Fries et al. 2013 for further information).

Asset Elements: Sidewalks and Curbs

Asset Elements of the *Roadside Features* Asset Class

Asset Element-specific Considerations

Sidewalks are the paved or otherwise constructed asset element between the edges of roadway shoulders and the right-of-way line intended for pedestrian or other non-motorized use. Curbs are the transitional edges where raised surfaces, typically sidewalks, meet unraised roadway surfaces. Curbs include ramps with a tapering area to allow for wheelchair access. Typically DOTs do not maintain significant amounts of sidewalks and curbs but rather local jurisdictions often own and maintain sidewalks and curbs. Some DOTs share sidewalk maintenance responsibilities with local governments or transfer sidewalk maintenance responsibilities to local governments once sidewalks are in service (Markow 2007).

Nonetheless, the lifecycle management activities associated with sidewalks and curbs present a unique challenge for DOTs in terms of compliance with the Americans with Disabilities Act (ADA). The ADA requires all state and local governments to perform a self-evaluation that identifies program access issues, as defined by the law. A 2004 court case identified sidewalks as an ADA program. Non-compliance with the ADA presents a significant legal risk for DOTs and can result in substantial legal settlements. For example, the City of Chicago settled a case in 2007 and in addition to its $18 million annual sidewalk maintenance budget, agreed to spend an additional $10 million for five years (Loewenherz 2010).

ENTERPRISE-LEVEL

Inventory

Sidewalk and curb asset element inventories are typically maintained in standalone databases/systems. This sidewalk and curb asset element inventory should contain essential data items including location, condition, and age and may also contain additional data items such as material type, deterioration rate, expected remaining service life, etc. If sidewalk and curb asset elements are within the jurisdiction of a DOT, a complete, i.e., 100%, inventory should be maintained to mitigate the risk of ADA non-compliance legal action. DOTs with Enterprise Asset Management Systems (EAMS) should link sidewalk and curb asset element inventories to the EAMS inventory as the inventory of record.

Interaction between Asset Classes

Sidewalk and curb asset elements form a key component of the pedestrian transportation network. ADA compliant sidewalks and curbs in acceptable condition not only mitigate legal risk to DOTs, but can also improve pedestrian comfort, safety, and mobility.

Relationship with Overall Safety, Mobility, Asset Performance

Pedestrian comfort and level of service, along with ADA compliance, are essential components of a comprehensive, multimodal transportation system. Adequate sidewalk and curb networks can improve pedestrian safety and mobility. For example, the Florida DOT measures pedestrian comfort using a pedestrian level of service that accounts for the following factors: presence of a sidewalk, lateral separation of the sidewalk from motor vehicle traffic, barriers and buffers between pedestrians and motor vehicle traffic, motor vehicle volume and composition, effects of motor vehicle traffic speed, and driveway frequency and access volume (Markow 2007).

ASSET SPECIFIC-LEVEL

Inspection and Condition Assessment

Visual inspection is the most commonly used technique to assess sidewalk condition, which is typically measured using a simple condition rating scale (e.g., scale of 1 to 5). There are automated techniques to assess sidewalk and curb asset element condition although these techniques typically are more costly. For example, the City of Bellevue, Washington partnered with King County, Washington and the FHWA to conduct a pilot study to inventory and assess the condition of sidewalk and curb asset elements using an Ultra-Light Inertial Profiler (ULIP) mounted on a Segway scooter, to collect sidewalk data (see Loewenherz 2010 for more detail).

Once DOTs establish an initial inventory of sidewalk and curb asset elements within their jurisdictions, there is considerable variation in the frequency of sidewalk and curb asset element inspection, which can vary from once

every two or four years to every 20 years; the primary drivers for inspection and condition assessment are customer complaints (Markow 2007).

Level of Service/Performance Metrics

Among the most common performance metrics for sidewalks and curb asset elements is whether or not these asset elements are ADA compliant. Typically agencies use simple condition rating scales comparing current sidewalk and curb condition to both ADA compliance and originally intended function are used. The service life for sidewalks and curbs is relatively long and one study estimated the service life of sidewalks at approximately 50 years (Haas et al. 2008). Although surveys indicate an estimated maximum concrete sidewalk service life of 60 years, the median is approximately 25 years for concrete sidewalks, 20 years for brick or block sidewalks, and 10 years for asphalt sidewalks (Markow 2007).

Life cycle Management Plans and Practices

The ADA requires that agencies conduct self-evaluations, which must identify program access issues. Beyond the identification of access issues, DOTs should establish a minimum acceptable level of condition, which is tied to ADA compliance, for sidewalk and curb asset elements. This should involve the development of a long-term preventive maintenance and replacement programs for sidewalk and curb asset elements (see Haas et al. 2008). As sidewalk and curb asset elements deteriorate, DOTs should plan to repair, rehabilitate, and/or replace these asset elements to ensure maximum service life at the lowest life cycle cost. In addition, DOTs can estimate future needs for life cycle management activities related to sidewalk and curb asset elements by tracking historical life cycle management activities.

Asset Prioritization

Sidewalk and curb asset elements identified as non-ADA compliant should be prioritized for life cycle management activities to address ADA non-compliance issues. User complaints are also likely to drive the prioritization of identified sidewalk and curb asset elements for life cycle management activities.

Decision Support

DOTs should track life cycle management activities and costs associated with sidewalk and curb asset elements. These historic activities and costs can be used to inform future needs estimates. In addition, DOTs can track the actual service life of sidewalk and curb asset elements and compare it to service life estimates to assess the suitability of certain material types and designs for local environmental conditions.

Additional References

Along with local agency partners, the FHWA sponsored a pilot program to prototype automated sidewalk and curb asset element data collection and condition assessment (see Loewenherz 2010 for more information). A study in Edmonton, Alberta, Canada estimated the service life of sidewalk and curb asset elements at 50 years and predicted the impact of various life cycle management activities and funding scenarios on side condition over one asset life cycle, i.e., 50 years (see Haas et al. 2008).

CHAPTER 6: LITERATURE REVIEW

This chapter presents a summary of the literature that was reviewed to both define an asset hierarchy and to identify existing information and guidance on life cycle management activities of ancillary assets. A complete listing of the reviewed literature is presented in *References*.

The *Transportation Asset Management Guide Vol. 2: A Focus on Implementation* identifies three key principles that drive transportation asset management (AASHTO 2011):

- Recognizing the economic value of assets
- Achieving economic efficiency and optimization of expenditure over an asset's life cycle
- Agency stewardship of assets

This guide also encourages a life cycle management approach that takes a long-term view of infrastructure performance and cost, encourages cost-effective preventative strategies, and builds confidence in resource allocation while also fostering stakeholder buy-in. Life cycle asset management considers costs and benefits, involves stakeholders and customers, requires consideration of future outcomes and not just current performance, and optimizes the timing of rehabilitation and replacement. The guide suggests the following steps in a life cycle asset management process (AASHTO 2011):

1) Establish levels of service
2) Monitor performance
3) Identify deficiencies
4) Determine if action is warranted
5) Estimate cost and effect of alternatives
6) Evaluate and select action
7) Group actions into projects
8) Set priorities
9) Match projects to programs

NCHRP Report 632 developed a framework to apply asset management principles and practices to maintain Interstate Highway System (IHS) assets and provides guidance for all IHS assets, not just pavements and bridges. This report focuses on the Interstate System under the premise that IHS assets constitute the most critical highway assets in the U.S. Recognizing that asset management systems for assets other than pavements and bridges are typically elementary, the report recommends that condition on ancillary assets be reported on the basis of whether these assets are "functioning as intended" (Cambridge Systematics et al. 2009).

In line with this approach, when budgeting for future needs for ancillary assets, a maintenance level of service or remaining service life approach is recommended. Basic data collection needs for all asset types include location, inventory, and condition data, with additional information required to model performance and predict condition and performance based on funding levels. Ancillary structures, including tunnels, culverts/drainage structures, noise barrier walls, retaining walls, overhead sign structures, and high mast light poles, should be inventoried and inspected on two or four year cycles. These structural assets have the potential to impact overall roadway system safety and performance, resulting in the closure of a segment of the IHS and thus should receive higher priority in terms of inventory, inspection and condition assessment (Cambridge Systematics et al. 2009).

NCHRP Report 677 discussed the Maintenance Quality Assurance (MQA) processes many state DOTs use to report the performance and condition of ancillary assets with the IHS right-of-way. For roadside features, drainage systems, and traffic control devices a consistent approach towards MQA for these asset classes can be developed based upon the best practice information documented in this report. In many states the aim of the MQA programs is to evaluate asset performance and develop a performance based budget (Dye Management Group et al. 2010).

NCHRP Synthesis 371 analyzed the state-of-the-practice in the management of transportation assets other than pavements and bridges, with a focus on the following asset classes (Markow 2007):

- Traffic signals – including structural components
- Lighting – including structural components
- Signs – both ground-mounted and overhead; including structural components
- Pavement line striping and other markings
- Drainage culverts and pipes
- Sidewalks

The Synthesis examined several key areas of asset management for the aforementioned asset classes. Several of the areas examined included budgeting for preservation, operation, and maintenance, measuring asset condition and performance, methods and frequencies of data collection, and estimating service lives. There are multiple challenges associated with managing ancillary assets. Typically the responsibility for managing these assets is not confined to one unit or division within an organization, and the materials and components of ancillary assets vary widely, as do the environment conditions these assets are exposed to. Results of the survey conducted for this Synthesis indicate that several agencies have developed management systems for individual asset classes or incorporated certain asset classes into broader enterprise asset management systems or maintenance management systems. Agencies generally agreed that ancillary assets should be managed but at the time the survey was conducted agencies lacked complete inventories of ancillary assets, standardized knowledge in terms of performance and service life for selected asset classes, modeling tools, and other analytical tools to improve decision making without additional data collection (Markow 2007).

There is overlap between the analysis in *NCHRP Synthesis 371* and this research effort for all of the asset classes except for pavement line striping and other markings, which were not selected for further analysis by the project panel. Useful results from the synthesis include information on management practices, performance measurement, service life, and information technology used to manage each asset class (Markow 2007). Although it did not specifically focus on ancillary assets, *NCHRP Synthesis 439* captured the state-of-the-practice as it relates to collecting inventory and condition data on the following asset classes (Hawkins & Smadi 2013):

- Pavements
- Bridges
- Signs
- Guardrail
- Culverts
- Lighting
- Pavement Markings
- Retaining Walls
- Other

Results of the survey indicate that beyond pavements and bridges, additional asset classes that are most commonly inventoried include signs, guardrail, and culverts respectively. Presumably, anticipation of federal retroreflectivity standards had an impact on the number of DOTs with sign inventories. The *Manual on Uniform Traffic Control Devices* (MUTCD), which is part of the Federal Register and defines standards for all traffic control devices on public roads and private roads accessible by the public (FHWA 2009), mandated new minimum sign retroreflectivity standards in 2007. The FHWA compliance requirements for the retroreflectivity standards mandate the "…implementation and continued use of an assessment or management method that is designed to maintain regulatory and warning sign retroreflectivity at or above the established minimum levels…" by June 2014 (FHWA 2012a).

Even though many DOTs are moving towards collecting more comprehensive asset inventories, additional work can be done to implement life cycle management processes utilizing these inventories along with appropriate tools, processes, and analytical techniques (Hawkins & Smadi 2013). Existing knowledge and industry practices can be used to develop best practices for the life cycle management business processes for the asset classes selected for further analysis in this study effort.

Although the value of ancillary assets may not be as great as roadway and bridge assets, many of these assets serve critical functional roles in the transportation network. As such, ancillary asset management, in the context of broader asset management systems, can lead to improved budgeting and prioritization of ancillary assets (Amekudzi et al. 2011). Effective life cycle management of ancillary assets can also benefit from life cycle cost analysis (LCCA). Although LCCA is not required for ancillary asset management, and many transportation agencies maintain ancillary assets without the use LCCA, its primary benefit is an improved understanding of the service life of an asset.

NCHRP Synthesis 371 (Markow 2007) estimates service life for the following six asset types:

- Traffic Signals
- Roadway Lighting
- Signs
- Pavement Markings
- Drainage Culverts
- Sidewalks

In conjunction with installation costs, annual operations and maintenance costs, and an inventory of the six aforementioned asset types, an agency could estimate the life cycle costs of those assets. Further information is provided in *NCHRP Report 713* (Thompson et al. 2012), which discusses estimating service life for highway assets, inclusive of culverts, signs, signals, pavement markings and lighting. This report also provides detailed definitions of the various aspects of an asset's life, including: physical life, functional life, service life, and economic life. Further definitions are given for the following criteria used to define asset life: actual life, estimated life, target life, and design life (Thompson et al. 2012). Well-defined criteria for asset service life can not only extend an asset's life but also greatly improve planning and budgeting activities.

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APPENDIX B: LIFE CYCLE MANAGEMENT SURVEY

Asset Class:	
Asset Description and Risk Profile	
Please provide a short description of this asset class (definition, sub-assets, function, importance)	
Inventory	
What is the extent of the agency's current inventory (comprehensiveness, accuracy, etc.)?	•
What is the commissioning / new assets and decommissioning process?	•
Please indicate the agency's inventory data collection process (for "unknown" assets)?	•
Where is the inventory data currently stored? (systems in use)	•
Inspection and Condition Assessment	
What methods does the agency use to collect condition data for this asset class?	•
How does the agency monitor condition for this asset class?	•
What is the frequency for updating condition data?	•
Where is the condition data currently stored (systems in use)	•
Level of Service / Performance metrics	
How does the agency measure condition of this asset, and what are the level of service metrics?	•
Life cycle management plans and practices	
Does the agency have an established life cycle management plan for this asset class? (Yes/No) Please explain.	•
What are the different treatments	•

Asset Class:	
that are applied to this asset class for routine and preventive maintenance, rehabilitation and replacement? How does the agency forecast the treatments and costs?	
How does the agency forecast "reactive maintenance needs" - impact on performance due to other factors (e.g. crash, vandalism, etc.)	•
How does the agency determine where an asset is within its life span? What conditions trigger particular treatment actions relative to expected level of service? Please explain	•
Are there any design, maintenance or other considerations that the agency undertakes to help reduce life cycle costs?	•
Please indicate the systems in use that help determine asset treatments and costs	•
Asset Prioritization	
How are treatments among different assets (within an asset class) prioritized based on funding constraints?	•
How is funding prioritized between different asset classes?	•
Please indicate the systems in use that help prioritize asset treatments (both within an asset class and between asset classes)	•
Decision Support	
How are actual costs tracked and	•

Asset Class:	
stored?	
How are actual costs used to update future cost estimates?	•
Is actual service life tracked for assets? If yes, how?	•
Is actual service life used to update future service life forecasts? If yes, how?	•
Interaction between asset classes	
How does the agency handle/quantify relationships between this asset class and between other asset classes, including risk analysis (e.g. between drainage and pavements)	•
Relationship of asset class to overall safety, mobility, asset performance	
How does the agency handle/quantify relationships between this asset class and system performance, including risk analysis (e.g. between ITS assets and mobility)	•
Other	
Please indicate any other information for this asset class	•