Life Cycle Planning for Intelligent Transportation System Assets: Survey of Practice

Requested by
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Executive Summary

Background

California Department of Transportation (Caltrans) is exploring methodologies for assessing the life span of ITS assets in the following categories:

- Changeable message signs (CMS).
- Closed circuit televisions (CCTV).
- Extinguishable message signs.
- Highway advisory radios (HAR).
- Ramp metering systems.
- Roadway weather information systems (RWIS).
- Traffic census stations.
- Traffic monitoring detection stations.
- Traffic signals.

ITS assets may have multiple elements with varying life expectancies and at various stages of useful life. An asset may be replaced to address issues with accuracy, evolving standards, compatibility with technology, technology obsolescence or element damage, or service life.

Caltrans is seeking information from other state departments of transportation (DOTs) about practices that estimate the life span of ITS assets installed on state highways. The agency is interested in methodologies used by other DOTs to conduct a life expectancy analysis of various components of an ITS asset; the frameworks that identify an asset's life expectancy, calculate remaining service life, and schedule maintenance and replacement; and performance measures used to track ITS assets.

Summary of Findings

Survey of Practice

An online survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Transportation System Operations, which includes the Working Group on Intelligent Transportation Systems. Eighteen state DOTs responded to the survey; of this group, 11 agencies gather data to conduct life cycle planning for ITS assets of interest to Caltrans:

- Illinois.
- Maine.
- Michigan.
- Montana.
- Nevada.
- Oregon.
- Pennsylvania.
- South Dakota.
- Utah.
- Virginia.
- Wisconsin.

Respondents from Illinois, Michigan, Nevada, Pennsylvania and South Dakota DOTs indicated that their work with ITS asset life cycle planning practices is preliminary. Montana DOT currently only replaces assets as needed (such as damaged equipment or projects necessitating removal). The Oregon DOT respondent provided a partial response to the survey, explaining that while the agency relies and uses a lot of data in its asset management process, "human judgment" is also involved in planning for asset replacement. The agency's operations program includes a condition rating system for traffic signals only.

A respondent from West Virginia DOT reported that the agency gathers data for life cycle planning, however, the respondent did not provide details about these practices. Respondents from six states reported that their agencies do not gather life cycle planning data.

Intelligent Transportation System Assets

Below are highlights from the 11 responding agencies that have experience with life cycle planning for ITS assets. Significantly more information about these practices, including methodologies used to assess asset condition, impact of maintenance activities on asset service life, circumstances that lead agencies to improve the condition of an asset and the influence of industry obsolescence on an asset, is presented in the **Detailed Findings** section of this Preliminary Investigation.

Changeable Message Signs

Asset Condition

All 11 states gather data to conduct life cycle planning for CMS. The CMS in six states (Nevada, Oregon, Pennsylvania, South Dakota, Utah and Wisconsin) have multiple components. Three states (South Dakota, Utah and Wisconsin) track the life span of each component part. States determine overall condition based on a specific part, such as the message board (Illinois) or dynamic message sign (DMS) controller and display (South Dakota); sign age (Pennsylvania); or a deterioration model/condition rating system (Nevada and Utah).

To evaluate CMS condition, agencies primarily use age-based assessments (11 states), inspection reports (eight states) and engineering judgment (six states). While Nevada DOT's methodologies are mostly based upon the manufacturer's recommended life, the agency has been using an asset management program to track all work orders and is working to develop "a more robust," performance-based condition reporting system from this program. Four agencies apply standard categories in their condition reports: an age-based assessment (Michigan and Virginia); a rating of good, low risk, medium risk or high risk (Nevada); a rating from 1 (failed) to 5 (excellent) (Utah); condition (Virginia); warranty (Virginia); and manufacturer support (Virginia).

Most agencies inspect CMS annually (six states) and perform preventive maintenance annually (five states). Six states reported that maintenance activities extend the remaining service life of CMS; Utah DOT lacks the hard data to support this idea and is trying to collect needed data. Nevada DOT reported that once the agency has developed a more robust database system that tracks the life of each asset, it aims to use a performance-based approach to evaluate the asset's remaining life that will eventually tie in to its 10-year maintenance asset funding for investments. If a Pennsylvania DOT sign has a history of repeated repairs, it will be evaluated based on the 5 R's of maintenance (repair, retrofit, replace, relocate and remove).

Five agencies attempt to improve the condition of a CMS when it cannot be repaired, when functioning has degraded or when the device is no longer supported (Illinois, Montana, Oregon, South Dakota and Virginia). Other circumstances when asset condition is improved include when a road construction or replacement project is in the area (Michigan and Virginia); system upgrades (Virginia); and when a device is 15 years old or is among district replacement priorities (Pennsylvania). Utah DOT supports a time-based cycle to keep on top of assets and replace them before they fail, so that operations appear as seamless to the public.

Estimated Service Life

The estimated service life of CMS ranges from five years (one state) to 20 years (four states). As part of Nevada DOT's transportation asset management plan (TAMP), the agency uses a 10-year maintenance asset budget that is distributed annually for each of the devices recorded.

Nine states reported that industry obsolescence influences the estimated service life of CMS. When Illinois DOT is notified that asset parts will become obsolete, the agency begins to discuss replacing the asset within the next three to five years. Utah DOT also considers replacing the asset under these circumstances; as an example, the respondent noted that the agency's analog CCTV cameras are still functioning but because they are no longer supported by the manufacturer, the agency is replacing them with digital CCTV cameras.

Key factors that affect the remaining life of a CMS include age (11 states), condition (11 states) and manufacturer support (nine states). Nevada DOT uses inputs to a transition probability matrix to assess the change in condition rating (good, low risk, medium risk, high risk).

Intervals at which agencies replace CMS include at the end of its useful life (10 states), when replacement parts are no longer available (10 states), in connection with a roadway replacement or new construction project (eight states) and when it no longer functions as originally intended (seven states). Calculations used to determine remaining service life include the age of the CMS (two states) and change in condition rating (one state). Utah DOT bases its end-of-life replacement funding on the estimated percentage of each component that needs replacement each year multiplied by the cost to purchase and install each component.

Closed Circuit Televisions

Asset Condition

Nine states gather data to conduct life cycle planning for CCTV (Illinois, Michigan, Nevada, Oregon, Pennsylvania, South Dakota, Utah, Virginia and Wisconsin). Five states have CCTV with multiple components, and two states track the life span of each component part. Three states determine overall condition based on a specific part, such as the camera (Illinois and South Dakota) or the CCTV unit (Pennsylvania); two states use a deterioration model/condition rating system (Nevada and Utah).

To evaluate CCTV condition, agencies primarily use age-based assessments (seven states), inspection reports (six states) and engineering judgment (six states). While Nevada DOT's methodologies are mostly based upon the manufacturer's recommended life, the agency is working to develop "a more robust," performance-based condition reporting system. Two agencies apply standard categories in their condition reports: good to high risk (Nevada) and a rating from 1 (failed) to 5 (excellent) (Utah).

Agencies in four states inspect CCTV annually; agencies in three states perform preventive maintenance annually. Five states reported that maintenance activities extend the remaining service life of CMS. Agencies typically attempt to improve the condition of CCTV when functioning is degraded or the device is no longer supported (five states).

Estimated Service Life

The estimated service life of CCTV ranges from five to 15 years, with three states reporting a service life of 10 years and one state reporting 10 to 15 years. Key factors that affect the remaining service life of CCTV include age (seven states) and condition (seven states). Intervals at which agencies replace CMS include at the end of its useful life (six states), in connection with a roadway replacement or new construction project (six states), and when it no longer functions as originally intended (six states). Calculations used to determine remaining service life include a transition probability matrix to assess the change in asset condition rating (one state).

Extinguishable Message Signs

Asset Condition

Nevada and Wisconsin DOTs gather data to conduct life cycle planning for extinguishable message signs. Both agencies have assets with multiple components; Wisconsin DOT also tracks the life span of each component part. Nevada DOT uses a deterioration model to determine overall asset condition; Wisconsin DOT relies on maintenance history. Nevada DOT applies standard categories in its condition reports using a four-stage rating of good to high risk. In Wisconsin, these assets are inspected and maintained annually (preventive maintenance is performed when the signs are inspected). In Nevada, inspection and preventive maintenance intervals are based on type of asset using the following categories: inspections, minor repairs, major repairs and replacements.

Estimated Service Life

The estimated service life of extinguishable message signs is 20 years in Wisconsin. Nevada DOT uses a 10-year maintenance asset budget that is distributed annually for each of the devices recorded. Factors affecting remaining service life in Wisconsin are age, condition and manufacturer support; in Nevada, these factors are maintenance costs per unit, asset condition, network growth rate, fraction of the network that will receive each maintenance activity based on its condition, and weight factors associated with each condition for calculating the health index.

Funding availability determines when Nevada DOT replaces these assets. Wisconsin DOT replaces them when signs reach the end of their useful life, in connection with roadway replacement or a new construction project, when signs no longer function as originally intended and when replacement parts are no longer available.

Highway Advisory Radios

Asset Condition

Nevada and Pennsylvania DOTs gather data to conduct life cycle planning for HAR. Both agencies have assets with multiple components. Pennsylvania DOT tracks the life span of each component part. Pennsylvania DOT uses inspection reports to assess HAR condition. In addition to following manufacturer’s recommendations, Nevada DOT is tracking work orders in an asset management program that will be used to develop a performance-based condition reporting system. Nevada DOT applies standard categories in its condition reports using a four-stage rating of good to high risk. Pennsylvania DOT inspects HAR twice a year and performs preventive maintenance every two years. In Nevada, inspection and preventive maintenance intervals are based on type of asset using the following categories: inspections, minor repairs, major repairs and replacements.

Estimated Service Life

The estimated service life of HAR in Pennsylvania is 10 to 15 years. Nevada DOT uses a 10-year maintenance asset budget that is distributed annually for each of the devices recorded. Factors affecting remaining service life in Pennsylvania are age, condition, installation date, manufacturer support of device, physical environment, physical location and usage. In Nevada, these factors are maintenance costs per unit, asset condition, network growth rate, fraction of the network that will receive each maintenance activity based on its condition, and weight factors associated with each condition for calculating the health index.

Funding availability determines when Nevada DOT replaces these assets. Pennsylvania DOT replaces them in connection with a roadway replacement or new construction project, when the asset becomes obsolete, when it no longer functions as originally intended, when one or more components fail, and when replacement parts are no longer available.

Ramp Metering Systems

Asset Condition

Three states gather data to conduct life cycle planning for ramp metering systems (Illinois, Utah and Wisconsin). Utah and Wisconsin DOTs have systems with multiple components; both agencies also track the life span of each component part. Inspection reports are used by all three states to evaluate system condition; age-based assessment and engineering judgment are each used by two states.

Wisconsin DOT inspects ramp metering systems once a year; preventive maintenance is performed when systems are inspected. In Illinois, one district contracts maintenance inspections, which are conducted monthly for signal heads and quarterly for cabinets. The agency does not have a preventive maintenance schedule. Utah DOT's goal is to inspect and perform preventive maintenance semiannually, but the respondent noted that the agency is "fortunate" if these tasks are conducted annually.

Estimated Service Life

The estimated service life of ramp metering systems is 10 to 15 years in Illinois and 15 years in Wisconsin. In Utah, it varies depending on the component. Key factors that affect the remaining service life are age, condition, engineering judgment, physical environment and usage. Pavement detection is also a factor in Wisconsin. All three agencies replace systems in connection with a roadway replacement or new construction project. None of the agencies considers replacement when one or more components fail.

Roadway Weather Information Systems

Asset Condition

Nine states gather data to conduct life cycle planning for RWIS (Illinois, Maine, Michigan, Montana, Nevada, Pennsylvania, South Dakota, Utah and Virginia). RWIS in six states have multiple components; three states track the life span of each component part. The RWIS program in Pennsylvania is administered by another division within the agency, not by Traffic Operations/ITS. These devices are tracked based on a multiyear contract.

Inspection reports (six states) and age-based assessments (five states) are used to assess condition; four states use engineering judgment. Other assessment methodologies include performance (South Dakota), annual maintenance visits (Maine and Utah) and manufacturer's recommendations (Nevada). Nevada DOT is also developing a performance-based condition reporting system. RWIS inspections are conducted annually in four states; Montana DOT also inspects systems as needed for repairs, and Virginia DOT inspects the asset when an issue arises with a station. Preventive maintenance is performed annually in five states.

Circumstances for improving RWIS condition include during annual maintenance visits (Maine), as connectivity improvements become available (Montana) and when assets are not functioning as intended or when components fail (Michigan, South Dakota and Virginia). South Dakota DOT designs, integrates, installs and maintains its own RWIS installations, which makes most component replacements straightforward.

Estimated Service Life

The estimated service life of RWIS ranges from 10 to more than 20 years in five states. Key factors that affect the remaining service life of RWIS include condition, age, engineering judgment, manufacturer support and physical environment. Agencies most frequently replace RWIS at the end of its useful life (five states), in connection with a roadway replacement or new construction project (five states) and when the asset no longer functions as originally intended (five states). South Dakota DOT has not completely replaced the assets since adopting the current design, which is modular and can evolve with technological advances (components are replaced as necessary).

Traffic Census Stations

Asset Condition

Four states gather data to conduct life cycle planning for traffic census stations (Illinois, Pennsylvania, South Dakota and Wisconsin). Traffic census stations in Pennsylvania, South Dakota and Wisconsin have multiple components. South Dakota and Wisconsin DOTs track the life span of each component part.

Inspection reports are used by two states (Illinois and South Dakota) to evaluate traffic census station condition, followed by age-based assessments (Wisconsin) and engineering judgment (Wisconsin). South Dakota also considers performance in these assessments. Illinois DOT inspects cabinets and detection devices (such as loops, magnetometer, radar and Bluetooth) annually. In Wisconsin, information is downloaded daily. The agency performs repairs if data is missing, and calibrations are performed annually. Only South Dakota DOT reported on the frequency of preventive maintenance, which is conducted annually.

Estimated Service Life

Three agencies reported on the estimated service life of traffic census stations: 10 years in South Dakota and Wisconsin, and 10 to 15 years in Illinois. Key factors that affect the remaining service life of these assets include condition (three states) and age (two states). Agencies most frequently reported replacing traffic census stations in connection with a roadway replacement or new construction project (two states) and when the asset no longer functions as originally intended (two states).

Traffic Monitoring Detection Stations

Asset Condition

Five states gather data to conduct life cycle planning for traffic monitoring detection stations (Illinois, Michigan, South Dakota, Utah and Wisconsin). Assets in South Dakota, Utah and Wisconsin have multiple components. Three states also track the life span of each component part. All five states use inspection reports to evaluate asset condition. Three states also use age-based assessments and engineering judgment. Inspection is conducted annually in four states; preventive maintenance is performed annually in South Dakota and semiannually in Michigan.

Estimated Service Life

The estimated service life of traffic monitoring detection stations ranges from five years to 15 years. Key factors that affect the remaining service life of these assets are condition (five states) and age (four states). All five agencies replace the asset when it no longer functions as intended. Other replacement intervals include the end of the asset's useful life (four states), a road replacement or new construction project (three states) and failure to meet performance standards (three states).

Traffic Signals

Asset Condition

Six states gather data to conduct life cycle planning for traffic signals (Illinois, Montana, Pennsylvania, Utah, Virginia and Wisconsin). Traffic signals in all six states have multiple components. Utah, Virginia and Wisconsin DOTs track the life span of each component part. All six states evaluate traffic signal condition using inspection reports and age-based assessments. Other methodologies include engineering judgment (five states), preventive maintenance visits (one state) and maintenance history (one state).

Inspection and preventive maintenance intervals varied among state agencies. Virginia and Wisconsin DOTs inspect the assets annually. Virginia DOT also performs preventive maintenance annually; Wisconsin DOT performs preventive maintenance at the same time as the inspection. Utah DOT aims to inspect and perform preventive maintenance annually. Each year, Illinois DOT inspects and performs preventive maintenance on structures, mast arms, poles, signals interconnected with a railroad crossing and relamps signals still using incandescent lamps. However, it monitors closed-loop systems daily for error events (performed remotely); performs patrol (drive-by) inspections and preventive maintenance monthly; and inspects and maintains conflict monitors for multimeter units every other year.

Estimated Service Life

The estimated service life of traffic signals ranges from eight to 30 years in four states and varies based on the component in two states. Key factors that affect the remaining service life of traffic signals include condition (six states), age (five states), engineering judgment (five states), manufacturer support (five states) and advances in technology (five states). Agencies most frequently replace traffic signals in connection with a road replacement or new construction project (six states), when the asset no longer functions as planned (five states) and when replacement parts are no longer available (five states).

Other Life Cycle Planning Practices

Additional Devices in ITS Asset Inventory

Three agencies support additional devices in their ITS asset inventory:

- *Michigan*: all components (including supports, power supply, Ethernet switches and roadside units).
- *Utah*: Fiber optic communications systems, including hubs, switches, fiber cable, splice enclosures, junction boxes, air conditioning units at hubs, uninterruptible power supply, batteries and Gator Patches.
- *Wisconsin*: Portable CMS, portable traffic cameras and network communication hut.

ITS Asset Classification by Significance

Pennsylvania and Virginia DOTs classify ITS assets based on significance to agency operations. Statewide, Pennsylvania DOT focuses on CCTV, DMS, signals and HAR but districts may target additional devices. In Virginia, operation technology is, in many cases, life safety items.

Central Repository of ITS Asset Data

Nine agencies maintain a central repository of ITS asset data:

- *Maine*: MATS (Managed Assets for Transportation Systems). The agency partners with New Hampshire and Vermont transportation agencies on this system.
- *Michigan*: Asset Management Database (AMD), a web-based system.
- *Montana*: Data included in the agency's maintenance management system.
- *Nevada*: Nevada Data Exchange.
- *Pennsylvania*: The agency is migrating the ITS device inventory system into its Traffic Signal Asset Management System (TSAMS) tool. However, this has not evolved into a full asset management system with life cycle analysis capabilities.
- *South Dakota*: Asset management system exclusively for ITS devices.
- *Utah*:
  - Asset Inventory Management System (AIMS), developed internally to manage inventory and work orders.
  - WhatsUp Gold, a communications monitoring system that tracks the number of devices communicating.
- *Virginia*: The agency is currently developing a repository.
- *Wisconsin*: VUEWORKS software.

ITS Data Repository and Agency Transportation Asset Management System

In four states, the ITS data repository is separate from and does not interface with the agency's overall transportation asset management system (TAMS). One state has an ITS data repository that is separate from but does interface with that agency's TAMS; one state has an ITS data repository that is part of the agency's TAMS; and one state has an ITS data repository in which some of the data is in the agency's TAMS and some is separate, and the two do not interface. Nevada DOT's repository will eventually interface with its statewide asset management platform. In Utah, systems are used to help manually generate data needed for TAMS on an annual basis.

Use of Performance Measures

Utah DOT is overhauling its performance measures for ITS and traffic signals. It currently tracks inventory growth, percentage of devices communicating to its Traffic Operations Center (communications uptime) and traffic signal location condition (good, fair or poor). Pennsylvania DOT uses a monthly uptime calculation with a minimum requirement of 95% uptime. Virginia DOT uses performance measures to track traffic signals through visits to the individual signal location. Maine and Nevada DOTs are currently developing performance measures to track ITS assets, and Michigan DOT plans to use performance measures in the future.

Assessment and Recommendations

Successes and Challenges

Six states are still developing life cycle planning practices for ITS assets, making it too soon to report on successful strategies. Benefits reported by other agencies were:

- Enhanced access to funding and other resources.
- High uptime for devices.
- Ability to track information on both installations and components.

Agencies have encountered a number of challenges when conducting life cycle planning:

- Baseline data collection and accurate data on devices.
- Central system development.
- Coordination (design and construction).
- Cybersecurity.
- Device tracking (when tracking is assigned to multiple divisions) and failure.
- Funding.
- Maintenance history.
- Staffing.
- Unfamiliarity with practices.

Recommendations for Improving Life Cycle Planning Practices

Respondents offered recommendations for agencies seeking to improve life cycle planning practices for ITS assets. Below is a sampling of respondents' suggestions:

- Develop and use a system that tracks asset data and maintenance history (Maine, Michigan, Nevada, Pennsylvania, South Dakota and Wisconsin).
- Include life cycle planning practices in the state's certified TAMP (Nevada).
- Develop an ITS life cycle costing analysis tool (Nevada).
- Ensure a budget for future replacements (Montana and Wisconsin).
- Ensure constant communication with decision-makers both for funding purposes and support for personnel needs (Utah).

Agencies Not Conducting ITS Asset Life Cycle Planning

Six states do not gather data to conduct life cycle planning of ITS assets: Arkansas, Idaho, Massachusetts, New Jersey, North Dakota and Oklahoma. However, four are considering adopting a model or methodologies:

- Massachusetts DOT is considering an expansion of its asset management systems.
- New Jersey DOT is currently discussing adopting a model or methodologies.
- North Dakota DOT is working to establish a dedicated maintenance budget for ITS devices so that it can better track the replacement costs and life cycle costs of devices. (Currently each district is responsible for maintaining, repairing or replacing the devices, which makes it difficult for North Dakota DOT to track device condition.)
- Oklahoma DOT would adopt a model or methodology if it had more guidance or information.

While Idaho Transportation Department is not planning to adopt a model, the agency is collecting date information when new ITS devices are installed or replaced so that information about device age will be available in the future.

Related Research and Resources

A literature search of recent publicly available domestic and international in-progress and published research identified a representative sampling of publications that are organized into the following topic areas:

- National research and resources.

- State research and resources.
- International research and resources.
- Related resource.

Tables summarizing these publications, research in progress and other resources are presented by topic area beginning on page 13. Each table provides the publication or project title, the year of publication if research is completed, the source and a brief description of the resource. Significantly more detail about each resource can be found in the **Detailed Findings** section of this report.

Gaps in Findings

The survey gathered a reasonable response from state DOTs, and respondents provided a fair amount of detail about their agencies' life cycle planning practices. Other state transportation agencies that did not respond to the survey may have information and experience to share, and contacting these agencies could benefit Caltrans. Follow-up inquiries with survey respondents could also generate additional information of value to Caltrans.

Next Steps

Moving forward, Caltrans could consider:

- Reviewing each ITS asset category in the **Detailed Findings** section for information provided by respondents.
- Engaging with survey respondents to learn more about their agencies' life cycle planning practices.
- Contacting the West Virginia DOT respondent for details about the agency's life cycle planning practices.
- Maintaining contact with the four agencies that are considering adopting a life cycle planning model or methodologies (Massachusetts, New Jersey, North Dakota and Oklahoma DOTs).
- Reviewing the publications, in-progress research studies and other resources that supplement the survey findings along with the resources provided by survey respondents.
- Reaching out to nonresponding state transportation agencies for additional information of value to Caltrans.

National Research and Resources

Publication or Project (Date)	Source	Excerpt From Abstract or Description of Resource
Managing TMS Assets and Resources (2021)	National Operations Center of Excellence	Offers access to traffic management system (TMS) resources that include key findings from a TRB Annual Meeting workshop and a webinar examining performance measures and health indexes of ITS assets.
NOCoE Asset Management: Virtual Peer Exchange Proceeding Report (Spring 2021)	National Operations Center of Excellence	Describes a September 2020 virtual peer exchange that examined how transportation systems management and operations can be more integrated with agency asset management programs.
RITIS (Regional Integrated Transportation Information System) (2021)	Center for Advanced Transportation Technology Laboratory, University of Maryland	Provides data archiving and analytics capabilities for transportation data. RITIS tools can ingest nearly any type of data in any format, preserving historical data and providing seamless analysis across data providers and time ranges.
RITIS Platform Features and Applications Overview (2015)	Center for Advanced Transportation Technology Laboratory, University of Maryland	Describes and illustrates how transportation agencies can use RITIS. The system's three main components are real-time data feeds, real-time situational awareness tools and archived data analysis tools.
Intelligent Transportation Systems—Benefits, Costs and Lessons Learned: 2018 Update Report (March 2018)	U.S. Department of Transportation	Presents information on benefits, costs and lessons learned across nearly 20 years of ITS deployments, including a discussion of the benefits of ITS data archiving systems.
Transportation Asset Management for Ancillary Assets (April 2014)	National Cooperative Highway Research Program	Provides guidance on applying asset management practices to selected ancillary assets, including ITS equipment. The report includes discussion of enterprise asset management systems, which integrate data from multiple systems.
Operations Benefit/Cost Analysis TOPS-BC User's Manual: Providing Guidance to Practitioners in the Analysis of Benefits and Costs of Management and Operations Projects (June 2013)	Federal Highway Administration	Provides guidance on the setup and application of the Tool for Operations Benefit/Cost (TOPS-BC), which includes a framework and default cost data to estimate the life cycle costs of various transportation systems management and operations strategies.
NCHRP Report 713: Estimating Life Expectancies of Highway Assets, Volume 1: Guidebook (2012)	National Cooperative Highway Research Program	Presents a methodology for determining the life expectancies of major types of highway system assets, including traffic signals, for use in life cycle cost analyses.
NCHRP Report 713: Estimating Life Expectancies of Highway Assets, Volume 2: Final Report (2012)	National Cooperative Highway Research Program	Provides additional detail and background about theories and methods for estimating asset life expectancies.

Publication or Project (Date)	Source	Excerpt From Abstract or Description of Resource
Systems Engineering Guidebook for Intelligent Transportation Systems (November 2009)	Federal Highway Administration, California Division	Provides direction on applying systems engineering principles and practices to the development of ITS projects. ITS life cycle processes are discussed.
Implementation of Life-Cycle Planning Analysis in a Transportation Asset Management Framework (research in progress)	National Cooperative Highway Research Program	Provides guidance and analytical models for applying life cycle cost analysis as a component of a systemwide transportation asset management program. Completion date: November 2021.

State Research and Resources

Publication or Project (Date)	State	Excerpt From Abstract or Description of Resource
Technical Memorandum #7—Implementation Plan, Intelligent Transportation Systems Strategic Plan (October 2017)	Arizona	Outlines maintenance recommendations and requirements for ITS devices for the city of Buckeye, Arizona, including criteria for replacing or upgrading equipment. The memorandum includes a table of estimated life cycles for specific ITS devices.
Replacing Intelligent Transportation System Field Elements: A Survey of State Practice (January 2016)	California	Examines agencies' approaches to replacing ITS field elements as well as related issues of planning, funding and technology service life.
San Diego Region Intelligent Transportation Systems (ITS) Strategic Plan (August 2011)	California	Discusses ITS performance measures as part of the region's ITS strategic plan.
C.9. Intelligent Transportation Systems Technical Plan, Asset/Fund Management Guidebook (undated)	Colorado	Describes how Colorado DOT uses device functionality, age, life cycle and availability to prioritize maintenance and capital replacement activities for ITS equipment.
C.10. Traffic Signals Technical Plan, Asset/Fund Management Guidebook (undated)	Colorado	Provides guidelines for life cycle management for traffic signals, including estimated life spans for signal components.
Highway Transportation Asset Management Plan (August 2019)	Connecticut	Describes performance measures and life cycle planning for traffic signals.
Statewide Intelligent Transportation Systems Performance Measures (2016)	Florida	Reports on statewide progress regarding six ITS performance measures.
Integrated Environment for Performance Measurements and Assessment of Intelligent Transportation Systems Operations (July 2012)	Florida	Describes a data analysis tool that uses data collected by the state's traffic management centers and other sources to support performance measurement, transportation system modeling and ITS benefits assessment.

Publication or Project (Date)	State	Excerpt From Abstract or Description of Resource
Illinois Statewide Intelligent Transportation Systems (ITS) Strategic Plan (October 2019)	Illinois	Provides direction for the identification and prioritization of ITS projects, including a discussion of life cycle costs.
Importance of ITS Preventive Maintenance and Transitioning to an Accelerated ITS Design Approach for Illinois Tollway (September 2018)	Illinois	Discusses ITS infrastructure, preventive maintenance, cost–benefit analysis and transitioning to an accelerated ITS design phase.
Intelligent Transportation Systems (ITS) and Communications Systems Service Layer Plan (January 2018)	Iowa	Provides a guide for the deployment and operations of ITS technology and the underlying network communications system. The plan discusses maintenance planning, maintenance and inventory management tools, preventive maintenance, response maintenance, scheduled device replacement and performance management.
Implementation Recommendations for Management Procedures for Data Collected Via CAV (April 2018)	Michigan	Assesses the current state of the department's ITS and connected and automated vehicle (CAV) data systems and provides recommendations for developing integrated, dynamic and adaptive data management systems.
Management Procedures for Data Collected Via Intelligent Transportation Systems (September 2015)	Michigan	Makes recommendations for a statewide master/strategic plan for database aggregation across ITS, geographic information systems, and transportation asset management subsystems and programs.
Transportation Asset Management Plan (June 2019)	Minnesota	Provides a planning tool to help evaluate risks, develop mitigation strategies, analyze life cycle costs, establish asset condition performance measures and targets, and develop investment strategies. The plan includes information on ITS inventory and replacement value and on ITS data collection, management and reporting practices.
Manual of Guidelines for Inspection and Maintenance of Intelligent Transportation Systems (December 2009)	New Jersey	Provides a practical, state-of-the-art ITS inspection and maintenance manual and companion software tool. The tool is designed to help provide a cost-effective approach to inspecting, maintaining, upgrading and operating ITS equipment on roadways.
Intelligent Transportation Systems Maintenance Standards (2011)	Pennsylvania	Provides practitioners with a consistent framework for ITS maintenance, including baseline maintenance activities for specific devices and systems.
Warrants and Criteria for Installing and Sunsetting TxDOT ITS Equipment (January 2014)	Texas	Provides guidelines, criteria and procedures to assist with strategic decision-making related to installing, repairing and/or removing ITS field devices and systems. The report includes sunset requirements and criteria for determining when deployed ITS devices and systems should no longer be supported.
Decision Support System for Planning Traffic Operations Assets (2017)	Virginia	Presents a decision support system (DSS) for evaluation of controller software assets. The proposed DSS consists of four components—knowledge, model, dialog and database management—and uses a fuzzy analytic hierarchy process methodology.
ITS Strategic Plan 2010-2020 (March 2010)	Washington	Outlines a 10-year approach to implementing ITS infrastructure in Seattle, including

Publication or Project (Date)	State	Excerpt From Abstract or Description of Resource
		ITS performance measures.
WisTransPortal System (2019)	Wisconsin	Serves as a central source of traffic operations, safety and ITS data for Wisconsin highways, with specific capabilities for data archiving, real-time services and server applications development.

International Research and Resources

Publication or Project (Date)	Country	Excerpt From Abstract or Description of Resource
Reliability Centred Maintenance (RCM) for Intelligent Transport Systems (ITS) (2016)	Australia	Highlights the benefits of using a reliability-centered maintenance (RCM) framework for ITS assets to assign maintenance resources more efficiently. By applying engineering concepts such as engineering risk analysis, RCM uses operations and maintenance data to analyze failure modes and assign criticality.
Reliability-Centred Maintenance Strategy and Framework for Management of Intelligent Transport System Assets (2016)	Australia	Provides a reliability-centered maintenance (RCM) strategy and framework to manage ITS assets. The report covers identification of key success factors, confirmation of the benefits and acceptability of RCM within jurisdictions, design of an RCM process template and drafting of a road map for moving from the current practice to RCM.
Part 7: Intelligent Transport Systems Maintenance (November 2015)	Australia	Presents the minimum requirements for maintenance practices that will allow ITS devices to continue operating safely, reliably, efficiently and effectively for the duration of their economic service life.
Key Performance Indicators for Intelligent Transportation Systems (February 2015)	European Union	Reviews key performance indicators (KPIs) related to ITS, with a particular focus on the type, method of calculation and terminology used, and recommends a set of common KPIs for transportation.

Related Resource

Publication or Project (Date)	Source	Excerpt From Abstract or Description of Resource
A Life-Cycle Cost-Analysis Approach for Emerging Intelligent Transportation Systems With Connected and Autonomous Vehicles (January 2018)	New York University	Describes five fundamental differences of life cycle cost analysis (LCCA) between a conventional transportation system and a technology-oriented ITS deployment. The paper introduces a novel conceptual ITS LCCA framework to capture these differences.

Detailed Findings

Background

To improve project- and network-level decision-making, California Department of Transportation (Caltrans) is preparing to develop a standard methodology and procedure for estimating the life expectancy of intelligent transportation system (ITS) assets used on state highways. The key ITS assets in Caltrans' inventory include:

- Changeable message signs (CMS).
- Closed circuit television (CCTV).
- Extinguishable message signs (fixed message).
- Highway advisory radios (HAR).
- Ramp metering systems.
- Roadway weather information systems (RWIS).
- Traffic census stations.
- Traffic monitoring detection stations.
- Traffic signals.

ITS assets may be composed of multiple elements such as support structures, communication devices and electronic components, which all have a different life expectancy and can be at various stages of useful life. An ITS asset may be replaced to address the need for accuracy, evolving standards, compatibility with technology, technology obsolescence or element damage, or because the asset's useful life has been reached.

Caltrans is seeking information from other state departments of transportation (DOTs) about the methodologies used for estimating the life span of core elements of their ITS asset inventory. The agency is interested in exploring the methodologies used by other DOTs to conduct a life expectancy analysis of various components of an ITS asset; the frameworks that identify an asset's life expectancy, calculate remaining service life, and schedule maintenance and replacement; and performance measures used to track ITS assets.

Survey of Practice

An online survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Transportation System Operations, which includes the Working Group on Intelligent Transportation Systems. Survey questions are provided in Appendix A. The full text of survey responses is presented in a supplement to this report.

Summary of Survey Results

Transportation agencies from 18 states responded to the survey. Of this group, agencies from 11 states reported that they gather data to conduct life cycle planning for ITS assets of interest to Caltrans:

- Illinois.
- Maine.
- Michigan.
- Montana.
- Nevada.
- Oregon.
- Pennsylvania.
- South Dakota.
- Utah.
- Virginia.
- Wisconsin.

In addition, a respondent from West Virginia DOT reported that the agency does gather data for ITS asset life cycle planning but the respondent declined to provide details about the agency's practices.

DOT respondents from six states reported that their agencies do not gather life cycle planning data:

- Arkansas.
- Idaho.
- Massachusetts.
- New Jersey.
- North Dakota.
- Oklahoma.

Information provided by these agencies begins on page 63.

Below are survey results from the 11 DOTs that reported on their experience using life cycle planning practices for ITS assets. Information is presented in the following ITS asset categories:

- CMS.
- CCTV.
- Extinguishable message signs.
- HAR.
- Ramp metering systems.
- RWIS.
- Traffic census stations.
- Traffic monitoring detection stations.
- Traffic signals.

Each ITS category includes a discussion of asset condition and estimated service life. Supplementary resources provided by respondents are included as supporting documents.

Several agencies provided information to supplement their survey responses:

- Illinois, Michigan, Nevada, Pennsylvania and South Dakota DOTs indicated that their ITS asset life cycle planning practices are preliminary.
- Montana DOT currently only replaces assets as needed, such as damaged equipment or projects necessitating removal.
- The Oregon DOT respondent provided a partial response, giving details for the CMS category and only noting that it does gather data for CCTV. The respondent explained that while Oregon DOT relies and uses a lot of data in its asset management process, "human judgment" is also involved in planning for asset replacement. The agency's operations program includes a condition rating system for traffic signals only (see **Supporting Documents**). Asset life is based on experience, but not necessarily completely quantitatively derived. It is only one variable in a replacement decision. For example, the agency considers maintenance cost—or, specifically, assets that have an annual maintenance cost much higher than the mean for the same type of asset. (The DOT tracks all maintenance work in a maintenance management system.) Also, if a manufacturer goes out of business and replacement parts are no longer available, an asset may be replaced sooner than anticipated. Certain assets that are more critical get priority for replacement on a proactive, life cycle basis while other assets are fixed when they fail.
- In addition to completing the survey, the respondent from Virginia DOT described several approaches used by the agency:
    - If an asset no longer functions, is obsolete or does not conform to current federal or state mandates for design performance, then it should be replaced or overhauled. The triggers for asset replacement include trouble calls, inspection

outcomes, equipment or manufacturer obsolescence, age and condition, and changes in policy and/or industry standards.

- The agency contracts maintenance and support for many of the operations technology (OT) and ITS assets addressed in this Preliminary Investigation. Contractors develop and submit Obsolescence Management Plans annually that outline a very robust assessment approach for asset obsolescence management.
- Other factors considered in addition to age and condition, especially for OT/ITS assets where the average life cycle of the technology components is relatively short (five to 10 years), are:
  - Manufacturer support.
  - Opportunities to implement new capabilities during roadway reconstruction (such as upgrading cameras to HD or using full matrix/full color CMS).
  - Opportunities to shed legacy dependencies (use IP-based devices instead of serial devices or Power Over Ethernet (POE) when practical; move away from hard-to-acquire assets and spare parts.
  - Efficiencies in wholesale replacements of assets (such as by corridor or geographic area) to take advantage of mobilized and engaged resources, especially when increased maintenance of traffic is required (such as assets on interstates).
- Another strategy is to shift asset ownership and maintenance responsibility to third parties with specialized expertise in a given asset, which generally allows for deployment consistency. Examples include video aggregation and dissemination (Skyline); cloud-based services (AWS, Azure); resource sharing fiber (providers are responsible for fiber operation and maintenance for common sheath fiber); and co-location facilities with a monthly fee or fee that is negotiated into resource sharing agreements, which has allowed the agency to forego building a secure, climate-controlled network hub building with commercial and backup power. In these examples, the third party is responsible for providing technology refreshes to ensure consistent service, and Virginia DOT avoids life cycle management, inventory management or training staff on specialized technologies and services.
- Fund replacement is accomplished based on needs assessment and subsequent developed priorities. Virginia DOT uses a variety of funding sources and methods.

Changeable Message Signs

All 11 states gather data to conduct life cycle planning for CMS.

Asset Condition

CMS in six states (Nevada, Oregon, Pennsylvania, South Dakota, Utah and Wisconsin) have multiple components. Three states (South Dakota, Utah and Wisconsin) track the life span of each component part. To determine overall asset condition, agencies consider specific parts such as the message board (Illinois), sign age (Pennsylvania) and overall assessment (Virginia). Nevada DOT uses a deterioration model. Utah DOT is currently implementing a new system that rates each component on a scale from 1 to 5 (1 = dead/failed; 5 = excellent/new condition). The overall condition is the average of each component condition. Table 1 summarizes survey responses.

Table 1. Description of CMS Components

State	Multiple Components	Component Description	Life Span of Each Part Tracked	Part That Determines Overall Condition
Illinois				Message board
Nevada	X	• Inspections • Minor and major repairs • Replacements		Developed a deterioration model using a transition probability matrix (see **Supporting Documents**).
Oregon	X	Major components only		N/A*
Pennsylvania	X	• Sign type • Structure type • Power type • Cabinet, controller • UPS • Modem • Switches		Sign age
South Dakota	X	• Support structure • Dynamic message sign (DMS) controller and display • Power • Communications	X	DMS controller and display
Utah	X	• Controller • Sign • Communications equipment	X	• Implementing new system that rates each component on a scale of 1 to 5 (1 = dead/failed; 5 = excellent/new condition). • Overall condition: Average of each component condition.
Virginia				• Overall look at age and condition. • Manufacturer support. • New opportunities. • Legacy support. • Any efficiencies.
Wisconsin	X	• Sign bridge structure • Sign housing • LED board • Power supplies • Controller • Cabinet/components	X	N/R

N/R No response.

* Oregon DOT currently only has a condition rating for traffic signals.

Methodologies Used to Assess Condition

To evaluate CMS condition, all 11 states use an age-based assessment, eight states use inspection reports and six states used engineering judgment. Respondents also described other methodologies used to assess asset condition, such as an annual or semiannual maintenance visit (Maine and Utah) or maintenance history (South Dakota and Wisconsin). While Nevada DOT's methodologies are mostly based upon the manufacturer's recommended life for an asset, the agency has been using an asset management program to track all work orders and is working to develop "a more robust," performance-based condition reporting system from this program. Table 2 summarizes survey responses.

Table 2. CMS Condition Assessment Methodologies

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Illinois	X	X	X		
Maine		X		X	Annual maintenance visit.
Michigan	X	X	X		
Montana	X	X	X	X	Very basic evaluation of usability from maintenance/inspection.
Nevada	X	X		X	• Primarily manufacturer's recommended life. • Tracking work orders in an asset management program that will be used to develop a performance-based condition reporting system.
Oregon		X		X	Maintenance and repair costs compared to average costs for same type of asset.
Pennsylvania		X			
South Dakota	X	X		X	Maintenance history.
Utah	X	X	X	X	Annual/semiannual preventive maintenance visits by internal ITS staff.
Virginia	X	X	X	X	• Overall look at age and condition. • Manufacturer support. • New opportunities. • Legacy support. • Any efficiencies.
Wisconsin	X	X	X	X	Maintenance history.
Total	**8**	**11**	**6**	**8**	

Standard Categories in Condition Reports

Four state agencies apply standard categories in their condition reports:

Michigan: Age-based assessment

Nevada:

- Good.
- Low risk.
- Medium risk.
- High risk.

Utah:

- 1 = Failed (not working).
- 2 = Poor (damaged with intermittent failures).

- 3 = Fair (damaged but still working or working but obsolete).
- 4 = Good (working condition, not new).
- 5 = Excellent/new.

Virginia:

- Age.
- Condition.
- Warranty.
- Manufacturer support.

Inspection Interval

Inspections of CMS are most commonly conducted once a year (six states) followed by twice a year (one state) and every two years (one state).Utah DOT's goal is to inspect devices semiannually, but the respondent noted that the agency is "fortunate" if these assets are inspected annually. Nevada DOT's inspection interval is based on asset type; the agency uses four categories: inspections, minor repairs, major repairs and replacements. Table 3 summarizes survey responses.

Table 3. Inspection Interval for CMS

State	Semiannually	Annually	Biennially	Other	Description
Illinois				X	One district contracts out maintenance that includes monthly inspections of signs and quarterly inspections of cabinets.
Maine		X			
Michigan		X			
Montana			X	X	As needed when problems occur.
Nevada				X	• Based on asset type. • Four categories: ○ Inspections ○ Minor repairs ○ Major repairs ○ Replacements
Oregon		X			
Pennsylvania	X				
South Dakota		X			
Utah				X	Goal: Semiannually for most devices, but "fortunate" if conducted annually.
Virginia		X			
Wisconsin		X			
Total	**1**	**6**	**1**	**4**	

Preventive Maintenance Frequency

Preventive maintenance on CMS is most commonly conducted once a year (five states), followed by semiannually (two states). Montana DOT performs preventive maintenance every two years. Wisconsin DOT performs preventive maintenance when it inspects assets. Table 4 summarizes survey responses.

Table 4. Preventive Maintenance Frequency for CMS

State	Semiannually	Annually	Biennially	Other	Description
Illinois		X			
Maine		X			
Michigan		X			
Montana			X		
Nevada				X	• Based on asset type • Four categories: ○ Inspections ○ Minor repairs ○ Major repairs ○ Replacements
Oregon		X			
Pennsylvania	X				
South Dakota	X				
Utah				X	Goal: Semiannually for most devices, but “fortunate” if conducted annually.
Virginia		X			
Wisconsin				X	Inspection and preventive maintenance occur at the same time.
Total	**2**	**5**	**1**	**3**	

Impact of Maintenance Activities on Service Life

Maintenance activities extend the remaining service life of CMS according to respondents from Illinois, Maine, Oregon, Utah and Wisconsin DOTs. The Utah DOT respondent noted that while in theory, well-maintained devices tend to last longer, the agency doesn’t have hard data to support this belief and is trying to collect needed data. The Virginia DOT respondent reported that maintenance has some minimal impact on service life.

Other respondents provided the following information about agency maintenance activities:

- *Michigan*: Maintenance activities are considered on the modern (up-to-date) DMS.
- *Nevada*: Once the agency has developed a more robust database system that tracks the life of each asset, it aims to use a performance-based approach to evaluate the asset’s remaining life that will eventually tie in to its 10-year maintenance asset funding for investments.
- *Pennsylvania*: If a sign has a history of repeated repairs, it will be evaluated based on the 5 R’s of maintenance (repair, retrofit, replace, relocate and remove).

Improving CMS Condition

Five agencies attempt to improve the condition of a CMS when it cannot be repaired, functioning is degraded or the device is no longer supported (Illinois, Montana, Oregon, South Dakota and Virginia). Michigan DOT assesses DMS for replacement when a road construction or replacement project is in the area, and Pennsylvania DOT replaces a device at 15 years or based on an annual survey to its districts about replacement priorities. Nevada DOT has categorized its asset network into four condition states (good, low risk, medium risk and high risk), and Utah DOT supports a time-based cycle to stay up-to-date on asset condition and replace assets before they fail so that operations appear seamless to the public. Table 5 summarizes survey responses.

Table 5. Determining When Agency Improves CMS Condition

Topic	State	Description
Annually	Maine, Pennsylvania	*Pennsylvania:* Annual survey to the districts about replacement priorities.
Device Age	Pennsylvania	15 years or older.
Support or Functioning Issues	Illinois, Montana, Oregon, South Dakota, Virginia, Wisconsin	*Illinois*: Asset cannot be repaired or is no longer supported. *Montana*: Component cannot be repaired. *Oregon*: CMS stops functioning or functions in a degraded condition. *South Dakota*: At the end of controller and display life (retrofit with new; otherwise, repair components as necessary). *Virginia*: • System upgrades. • Asset no longer supported. *Wisconsin*: Repair ticket or preventive maintenance.
Other	Michigan, Nevada, Utah, Virginia	*Michigan*: DMS assessed for replacement when a project is in the area. *Nevada*: Four condition states: • **Good**: Less than 80% of asset life (based on manufacturer-recommended device service life) has been used for 50% of the network. • **Low risk**: 80%-100% of asset life has been used for 50% of the network. • **Medium risk**: 100%-125% of asset life has been used for 50% of the network. • **High risk**: More than 125% of the asset life has been used for 50% of the network. *Utah*: Goal is to replace assets before they fail. *Virginia*: Included in construction projects or corridor improvements.

<u>Estimated Service Life</u>

The estimated service life of CMS is summarized below:

5 years	Virginia
10 years	Illinois, Maine and Nevada
15 years	Michigan
10-15 years	Pennsylvania
16 years	South Dakota

20 years	Montana, Oregon, Utah and Wisconsin
Other	Nevada: As part of its transportation asset management plan (TAMP), uses a 10-year maintenance asset budget that is distributed annually for each device recorded.

Influence of Industry Obsolescence on Estimated Service Life

Nine agencies reported that industry obsolescence influences the estimated service life of CMS if parts are no longer available or manufacturers no longer repair products (Illinois, Maine, Nevada, Oregon, Pennsylvania, South Dakota, Utah, Virginia and Wisconsin). If Illinois DOT is notified that asset parts will become obsolete, the agency begins to discuss replacing the asset within the next three to five years. Utah DOT also considers replacing the asset; as an example, the respondent noted that the agency's analog CCTV cameras are still functioning but because they are no longer supported by the manufacturer, the agency is replacing them with digital CCTV cameras. Pennsylvania DOT evaluates the asset based on the 5 R's of maintenance (repair, retrofit, replace, relocate and remove).

The Nevada DOT respondent reported that industry obsolescence does not specifically impact an asset's estimated service life because the agency uses a weighted factor table based on the health of that device.

Factors Affecting Remaining Service Life

All 11 states indicated age and condition as key factors that affect the remaining service life of CMS. Other significant factors include manufacturer support (nine states), engineering judgment (six states), installation date (four states), physical environment (four states) and physical location (four states).

Nevada DOT provided additional factors:

- Maintenance costs per unit.
- Asset condition.
- Network growth rate.
- Fraction of the network that will receive each maintenance activity based on its condition.
- Weight factors associated with each condition for calculating the health index.

The agency uses inputs to a transition probability matrix to assess the change in condition rating (good, low risk, medium risk, high risk) (see **Supporting Documents**). These inputs are based on expert judgment. The number of years from one condition state to another is based on the time it takes for 50% of devices in one condition state to deteriorate to the next condition state. For example, if 100 devices are in good condition and it takes four years for 50% of those devices to transition to a low risk condition, the good to low risk transition input would be four years. Table 6 summarizes survey responses.

Table 6. Factors Affecting Remaining Service Life of CMS

State	Age	Condition	Engineering Judgment	Installation Date	Manufacturer Support	Manufacturer Warranty	MTBF*	Technology Advances
Illinois	X	X	X	X	X			
Maine	X	X						

State	Age	Condition	Engineering Judgment	Installation Date	Manufacturer Support	Manufacturer Warranty	MTBF*	Technology Advances
Michigan	X	X	X		X			
Montana	X	X	X		X			
Nevada	X	X	X					
Oregon	X	X		X	X			X
Pennsylvania	X	X		X	X			
South Dakota	X	X			X	X		
Utah	X	X	X	X	X	X	X	X
Virginia	X	X	X		X	X		
Wisconsin	X	X			X			
Total	**11**	**11**	**6**	**4**	**9**	**3**	**1**	**2**

* MTBF: mean time before failure.

Table 6. Factors Affecting Remaining Service Life in CMS, Continued

State	Physical Environment	Physical Location	Usage	Other	Description
Illinois					
Maine					
Michigan					
Montana	X	X			
Nevada				X	Additional factors: • Maintenance costs per unit • Asset condition • Network growth rate • Fraction of the network that will receive each maintenance activity based on its condition • Weight factors associated with each condition for calculating the health index Inputs are provided to transition probability matrix (see **Supporting Documents**). The number of years from one condition state to another is based on the time it takes for 50% of devices in one condition state to deteriorate to the next condition state.
Oregon	X				
Pennsylvania		X	X		
South Dakota					
Utah	X	X	X		
Virginia		X			
Wisconsin	X		X		
Total	**4**	**4**	**3**	**1**	

Replacement Interval

Agencies most frequently reported replacing CMS at the end of its useful life or when replacement parts are no longer available (10 states each). Table 7 summarizes survey responses.

Table 7. CMS Replacement Interval

State	End of Useful Life	Road Replacement/New Construction	Failure to Meet Performance Standards	Obsolescence	No Longer Functions as Planned	Component Fails	Replacement Parts Not Available	Other
Illinois	X	X			X		X	
Maine	X							
Michigan	X	X			X		X	
Montana	X	X			X	X	X	
Nevada	X	X	X	X	X	X	X	Funding availability
Oregon	X		X	X	X		X	
Pennsylvania		X		X		X	X	
South Dakota	X			X			X	
Utah	X	X	X	X	X		X	
Virginia	X	X	X		X		X	
Wisconsin	X	X					X	
Total	**10**	**8**	**4**	**5**	**7**	**3**	**10**	

Calculations to Determine Remaining Service Life

Oregon and South Dakota DOTs determine remaining service life based on the age of the CMS. The Nevada DOT respondent referred to the transition probability matrix that the agency uses to assess the change in condition rating (see **Supporting Documents**). Utah DOT bases its end-of-life replacement funding on the estimated percentage of each component that needs replacement each year multiplied by the cost to purchase and install each component.

Closed Circuit Television

Nine states gather data to conduct life cycle planning for CCTV: Illinois, Michigan, Nevada, Oregon, Pennsylvania, South Dakota, Utah, Virginia and Wisconsin. Note: Oregon DOT did not provide details about the condition or estimated service life of this asset category.

Asset Condition

CCTV in five states (Nevada, Pennsylvania, South Dakota, Utah and Wisconsin) has multiple components. Two states (Utah and Wisconsin) track the life span of each component part. To determine overall asset condition, agencies reported evaluating cameras (Illinois, Michigan and South Dakota) or the CCTV unit as a whole (Pennsylvania and Virginia). Nevada DOT employs a deterioration model based on information from a transition probability matrix (see **Supporting Documents**). Utah DOT is implementing a system that rates each component on a scale of 1 to

5 (1 = dead/failed; 5 = excellent/new condition); the overall condition is the average of each component condition. Table 8 summarizes survey responses.

Table 8. Description of CCTV Components

State	Multiple Components	Component Description	Tracks Part Life Span	Part That Determines Overall Condition
Illinois				Camera
Michigan				Camera
Nevada	X	• Inspections • Minor and major repairs • Replacements.		Deterioration model using a transition probability matrix (see **Supporting Documents**).
Pennsylvania	X	• CCTV unit • Structure/pole • Cabinet • Power • Controller • UPS • Modem • Switches		CCTV unit
South Dakota	X	• Camera • Communications		Camera
Utah	X	• Camera • Encoder/decoder • Communications equipment	X	• Implementing new system that rates each component on a scale of 1 to 5 (1 = dead/failed; 5 = excellent/new condition). • Overall condition: Average of each component condition.
Virginia				CCTV unit
Wisconsin	X	• Camera assembly • Lowering device • Pole • Cabinet/components	X	N/R

N/R No response.

Methodologies Used to Assess Condition

To evaluate CCTV condition, seven states use an age-based assessment, six states use inspection reports and six states used engineering judgment. Other methodologies reported were maintenance history (South Dakota and Wisconsin), image quality (South Dakota) and functionality (Virginia). In addition to manufacturer recommendations, Nevada DOT is developing a performance-based condition reporting system from an asset management program that tracks all work orders, and Utah DOT conducts annual or semiannual preventive maintenance visits. Table 9 summarizes survey responses.

Table 9. CCTV Condition Assessment Methodologies

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Illinois		X	X		
Michigan	X	X	X		
Nevada	X	X	X	X	• Primarily manufacturer's recommended life • Tracking work orders in an asset management program that will be used to develop a performance-based condition reporting system.
Oregon					
Pennsylvania	X				
South Dakota		X		X	Image quality, maintenance history
Utah	X	X	X	X	Annual/semiannual preventive maintenance visits by internal ITS staff
Virginia	X	X	X	X	Functionality
Wisconsin	X	X	X	X	Maintenance history
Total	**6**	**7**	**6**	**5**	

Standard Categories in Condition Reports

Nevada DOT and Utah DOT apply standard categories in their condition reports:

Nevada:

- Good.
- Low risk.
- Medium risk.
- High risk.

Utah:

- 1 = Failed (not working).
- 2 = Poor (damaged with intermittent failures).
- 3 = Fair (damaged but still working or working but obsolete).
- 4 = Good (working condition, not new).
- 5 = Excellent/new.

Inspection Interval

CCTV inspections are most commonly conducted once a year (four states). Pennsylvania DOT conducts inspections twice a year; semiannual inspections is also the goal for Utah DOT, however, the respondent noted that the agency is "fortunate" if inspections are conducted annually. Table 10 summarizes survey responses.

Table 10. Inspection Interval for CCTV

State	Semiannually	Annually	Other	Description
Illinois		X		
Michigan		X		

State	Semiannually	Annually	Other	Description

Nevada			X	• Based on type of asset
				• Four categories:
				  ○ Inspections
				  ○ Minor repairs
				  ○ Major repairs
				  ○ Replacements

Pennsylvania	X			
South Dakota		X		
Utah			X	Goal: Semiannually for most devices, but “fortunate” if conducted annually.
Virginia			X	Real time
Wisconsin		X		
Total	**1**	**4**	**3**	

Preventive Maintenance Frequency

Preventive maintenance on CCTV is conducted once a year in three states and twice a year in one state. Preventive maintenance frequency is based on asset type in Nevada, and Wisconsin DOT conducts preventive maintenance when it inspects assets. Table 11 summarizes survey responses.

Table 11. Preventive Maintenance Frequency for CCTV

State	Semi annually	Annually	Other	Description
Illinois		X		
Michigan		X		

Nevada			X	• Based on type of asset
				• Four categories:
				  ○ Inspections
				  ○ Minor repairs
				  ○ Major repairs
				  ○ Replacements

Pennsylvania	X			
South Dakota		X		
Utah			X	Goal: Semiannually for most devices, but “fortunate” if conducted annually.
Wisconsin			X	Inspection and preventive maintenance occur at the same time.
Total	**1**	**3**	**3**	

Impact of Maintenance Activities on Service Life

Both Utah and Wisconsin DOTs noted that regular maintenance is intended to extend the asset’s service life. Utah DOT is trying to collect hard data to support this belief. Most maintenance in South Dakota is related to cabling; camera maintenance typically involves cleaning lenses and housings.

Nevada DOT is planning to use a performance-based approach to evaluate the asset's remaining life that will eventually tie in to the agency's 10-year maintenance asset funding for investments. In Pennsylvania, CCTVs with a history of repeated repairs are evaluated based on the 5 R's of maintenance (repair, retrofit, replace, relocate and remove).

Improving CCTV Condition

Five agencies attempt to improve the condition of a CCTV when functioning is degraded or the device is no longer supported (Illinois, Michigan, South Dakota, Virginia and Wisconsin). Pennsylvania DOT replaces a device at 15 years or based on an annual survey of its districts' replacement priorities. Nevada DOT has categorized its asset network into four condition states (good, low risk, medium risk and high risk), and Utah DOT supports a time-based cycle to stay up-to-date on asset condition and replace assets before they fail so that operations appear seamless to the public. Table 12 summarizes survey responses.

Table 12. Determining When Agency Improves CCTV Condition

<table>
<tr><th>Topic</th><th>State</th><th>Description</th></tr>
<tr><td>Annually</td><td>Pennsylvania</td><td>Annual survey to the districts about replacement priorities.</td></tr>
<tr><td>Device Age</td><td>Pennsylvania</td><td>15 years or older.</td></tr>
<tr><td>Support or Functioning Issues</td><td>Illinois, Michigan, South Dakota, Virginia, Wisconsin</td><td>Illinois: When asset is no longer supported or obsolete.
Michigan: When asset is no longer functioning as designed.
South Dakota: Malfunctioning cameras are repaired until image quality is no longer acceptable.
Virginia:
System upgrade
Unit stops working,
Wisconsin: Repair ticket or preventive maintenance.</td></tr>
<tr><td>Other</td><td>Nevada, Utah, Virginia</td><td>Nevada: Four condition states:
Good: Less than 80% of asset life (based on manufacturer-recommended device service life) has been used for 50% of the network.
Low risk: 80%-100% of asset life has been used for 50% of the network.
Medium risk: 100%-125% of asset life has been used for 50% of the network.
High risk: More than 125% of the asset life has been used for 50% of the network.
Utah: Goal is to replace assets before they fail.
Virginia: Construction project.</td></tr>
</table>

<u>Estimated Service Life</u>

The estimated service life of CCTV is summarized below:

5 years	South Dakota
5-8 years	Virginia
7 years	Wisconsin

10 years	Illinois, Michigan and Utah
10-15 years	Pennsylvania
Other	Nevada: As part of its TAMP, uses a 10-year maintenance asset budget that is distributed annually for each of the devices recorded

Influence of Industry Obsolescence on Estimated Service Life

Three agencies reported that industry obsolescence influences the estimated service life of CCTV. Wisconsin DOT reported that technology improvements drive estimated service life. Both Pennsylvania and Utah DOTs are replacing analog units with digital units. In Nevada, industry obsolescence does not specifically impact an asset's estimated service life because the agency uses a weighted factor table based on the health of that device.

Factors Affecting Remaining Service Life

Seven states indicated age and condition as key factors that affect the remaining service life of CCTV. Other significant factors include manufacturer support (five states) and milestones in technology advancements (four states). Nevada DOT provided additional factors:

- Maintenance costs per unit.
- Asset condition.
- Network growth rate.
- Fraction of the network that will receive each maintenance activity based on its condition.
- Weight factors associated with each condition for calculating the health index.

The agency provides inputs for a transition probability matrix that are based on expert judgment (see **Supporting Documents**). The number of years from one condition state to another is based on the time it takes for 50% of devices in one condition state to deteriorate to the next condition state. For example, if 100 devices are in good condition and it takes four years for 50% of those devices to transition to a low risk condition, the good to low risk transition input would be four years.

Table 13 summarizes survey responses.

Table 13. Factors Affecting Remaining Service Life of CCTV

State	Age	Condition	Engineering Judgment	Installation Date	Manufacturer Support	Manufacturer Warranty	MTBF*	Technology Advances
Illinois	X	X	X					X
Michigan	X	X	X		X			
Nevada								
Pennsylvania	X	X		X	X			X
South Dakota	X	X			X			
Utah	X	X	X	X	X	X	X	X
Virginia	X	X	X		X	X		
Wisconsin	X	X						X
Total	**7**	**7**	**4**	**2**	**5**	**2**	**1**	**4**

* MTBF: mean time before failure.

Table 13. Factors Affecting Remaining Service Life in CCTV, Continued

State	Physical Environment	Physical Location	Usage	Other	Description
Illinois					
Michigan					
Nevada				X	Additional factors: • Maintenance costs per unit • Asset condition • Network growth rate • Fraction of the network that will receive each maintenance activity based on its condition • Weight factors associated with each condition for calculating the health index Inputs are provided to a transition probability matrix (see **Supporting Documents**). The number of years from one condition state to another is based on the time it takes for 50% of devices in one condition state to deteriorate to the next condition state.
Pennsylvania		X			
South Dakota	X				
Utah	X	X	X		
Virginia	X	X	X		
Wisconsin					
Total	**3**	**3**	**2**	**1**	

Replacement Interval

Agencies most frequently reported replacing CCTV at the end of its useful life, in connection with roadway replacement or new construction projects, or when it no longer functions as originally intended (six states for each factor). Table 14 summarizes survey responses.

Table 14. CCTV Replacement Interval

State	End of Useful Life	Road Replacement/New Construction	Failure to Meet Performance Standards	Obsolescence	No Longer Functions as Planned	Component Fails	Replacement Parts Not Available	Other
Illinois	X	X		X	X			
Michigan	X	X	X		X		X	
Nevada								Funding availability
Pennsylvania		X			X	X	X	
South Dakota	X		X		X			
Utah	X	X	X	X	X		X	
Virginia	X	X	X		X			

State	End of Useful Life	Road Replace ment/New Construction	Failure to Meet Performance Standards	Obsoles cence	No Longer Functions as Planned	Component Fails	Replacement Parts Not Available	Other
Wisconsin	X	X		X				
Total	**6**	**6**	**4**	**3**	**6**	**1**	**3**	**1**

Calculations to Determine Remaining Service Life

To determine remaining service life, Nevada DOT uses a transition probability matrix to assess the change in asset condition rating (see **Supporting Documents**). Utah DOT bases its end-of-life replacement funding on the estimated percentage of each component that needs replacement each year multiplied by the cost to purchase and install each component.

Extinguishable Message Signs

Nevada and Wisconsin DOTs gather data to conduct life cycle planning for extinguishable message signs.

Asset Condition

Both agencies reported having extinguishable message signs with multiple components. In Wisconsin, those components include sign structure, sign housing, LED boards, sensor and cabinet. Wisconsin DOT tracks the life span of each component part. To determine overall asset condition, Nevada DOT employs a deterioration model based on information from a transition probability matrix (see **Supporting Documents**).

Methodologies Used to Assess Condition

To assess extinguishable message sign condition, Wisconsin DOT evaluates maintenance history. Nevada DOT primarily follows manufacturer's recommendations, but is also tracking work orders in an asset management program that will be used to develop a performance-based condition reporting system.

Standard Categories in Condition Reports

Nevada DOT applies standard categories—good, low risk, medium risk and high risk—in its condition reports.

Inspection Interval

Wisconsin DOT inspects extinguishable message signs annually. Nevada DOT determines the inspection interval based on type of asset using the following categories: inspections, minor repairs, major repairs and replacements.

Preventive Maintenance Frequency

In Wisconsin, preventive maintenance and inspection of extinguishable message signs occur at the same time. Nevada DOT determines the preventive maintenance frequency based on type of asset using the following categories: inspections, minor repairs, major repairs and replacements.

Impact of Maintenance Activities on Service Life

Wisconsin DOT noted that regular maintenance is intended to extend the asset's service life. Nevada DOT is planning to use a performance-based approach to evaluate the asset's remaining life that will eventually tie in to its 10-year maintenance asset funding for investments.

Improving Extinguishable Message Sign Condition

Wisconsin DOT attempts to improve the condition of extinguishable message signs during preventive maintenance or when a repair is requested. Nevada DOT has categorized its asset network into four condition states:

- **Good**: Less than 80% of asset life (based on manufacturer-recommended device service life) has been used for 50% of the network.
- **Low risk**: 80% to 100% of asset life has been used for 50% of the network.
- **Medium risk**: 100% to 125% of asset life has been used for 50% of the network.
- **High risk**: More than 125% of the asset life has been used for 50% of the network.

Estimated Service Life

The estimated service life of extinguishable message signs is summarized below:

20 years	Wisconsin
Other	Nevada: As part of its TAMP, the agency uses a 10-year maintenance asset budget that is distributed annually for each of the devices recorded.

Influence of Industry Obsolescence on Estimated Service Life

Industry obsolescence does not influence the estimated service life of extinguishable message signs in Wisconsin or Nevada. (Nevada DOT uses a weighted factor table based on the health of that device.)

Factors Affecting Remaining Service Life

In Wisconsin, the remaining service life of extinguishable message signs is influenced by age, condition and manufacturer support of the device. The following factors affect remaining service life in Nevada:

- Maintenance costs per unit.
- Asset condition.
- Network growth rate.
- Fraction of the network that will receive each maintenance activity based on its condition.
- Weight factors associated with each condition for calculating the health index.

The agency provides inputs for a transition probability matrix that are based on expert judgment (see **Supporting Documents**). The number of years from one condition state to another is based on the time it takes for 50% of devices in one condition state to deteriorate to the next condition state. For example, if 100 devices are in good condition and it takes four years for 50% of those devices to transition to a low risk condition, the good to low risk transition input would be four years.

Replacement Interval

Funding availability determines when Nevada DOT replaces extinguishable message signs. Wisconsin DOT replaces them at the end of a sign's useful life, in connection with roadway replacement or a new construction project, when the sign no longer functions as originally intended or when replacement parts are no longer available.

Calculations to Determine Remaining Service Life

To determine remaining service life, Nevada DOT uses a transition probability matrix to assess the change in asset condition rating (see **Supporting Documents**).

Highway Advisory Radios

Nevada and Pennsylvania DOTs gather data to conduct life cycle planning for HAR.

Asset Condition

Both agencies reported having HAR with multiple components. In Pennsylvania, those components are the HAR, highway advisory beacon, structure, cabinet, UPS, modem and switches. The agency tracks the life span of each component part. To determine overall asset condition, Pennsylvania DOT evaluates the HAR; Nevada DOT employs a deterioration model based on information from a transition probability matrix (see **Supporting Documents**).

Methodologies Used to Assess Condition

Pennsylvania DOT uses inspection reports to assess HAR condition. In addition to following manufacturer's recommendations, Nevada DOT is tracking work orders in an asset management program that will be used to develop a performance-based condition reporting system.

Standard Categories in Condition Reports

Nevada DOT applies standard categories—good, low risk, medium risk and high risk—in its condition reports.

Inspection Interval

Pennsylvania DOT inspects HAR twice a year. Nevada DOT determines the inspection interval based on type of asset using the following categories: inspections, minor repairs, major repairs and replacements.

Preventive Maintenance Interval

Pennsylvania DOT performs preventive maintenance every two years. Nevada DOT determines the preventive maintenance frequency based on type of asset using the following categories: inspections, minor repairs, major repairs and replacements.

Impact of Maintenance Activities on Service Life

In Pennsylvania, if an HAR or highway advisory beacon has a history of repeated repairs, the agency will evaluate it based on the 5 R's of maintenance (repair, retrofit, replace, relocate and remove). Nevada DOT is planning to use a performance-based approach to evaluate the asset's remaining life that will eventually tie in to its 10-year maintenance asset funding for investments.

Improving HAR Condition

Pennsylvania DOT attempts to improve the HAR's condition when the device age is 15 years or older, or based upon an annual survey about its districts' replacement priorities. Nevada DOT has categorized its asset network into four condition states:

- **Good**: Less than 80% of asset life (based on manufacturer-recommended device service life) has been used for 50% of the network.
- **Low risk**: 80% to 100% of asset life has been used for 50% of the network.
- **Medium risk**: 100% to 125% of asset life has been used for 50% of the network.
- **High risk**: More than 125% of the asset life has been used for 50% of the network.

<u>Estimated Service Life</u>

The estimated service life of HAR is summarized below:

10-15 years	Pennsylvania
Other	Nevada: As part of its TAMP, the agency uses a 10-year maintenance asset budget that is distributed annually for each of the devices recorded.

Influence of Industry Obsolescence on Estimated Service Life

If HAR replacement parts or manufacturer service support is limited, Pennsylvania DOT will evaluate the device based on the 5 R's of maintenance (repair, retrofit, replace, relocate and remove). Industry obsolescence does not influence the estimated service life of HAR in Nevada. The agency uses a weighted factor table based on the health of that device.

Factors Affecting Remaining Service Life

In Pennsylvania, the remaining service life of HAR is influenced by:

- Age.
- Condition.
- Installation date.
- Manufacturer support of device.
- Physical environment.
- Physical location.
- Usage.

The following factors affect remaining service life in Nevada:

- Maintenance costs per unit.
- Asset condition.
- Network growth rate.
- Fraction of the network that will receive each maintenance activity based on its condition.
- Weight factors associated with each condition for calculating the health index.

The agency provides inputs for a transition probability matrix that are based on expert judgment (see **Supporting Documents**). The number of years from one condition state to another is based on the time it takes for 50% of devices in one condition state to deteriorate to the next condition state. For example, if 100 devices are in good condition and it takes four years for 50% of those devices to transition to a low risk condition, the good to low risk transition input would be four years.

Replacement Interval

Funding availability determines when Nevada DOT replaces HAR. Pennsylvania DOT replaces the device in connection with a roadway replacement or new construction project, when it has become obsolete, when it no longer functions as originally intended, when one or more components fail or when replacement parts are no longer available.

Calculations to Determine Remaining Service Life

Pennsylvania DOT is phasing out HAR/highway advisory beacons. Based on surveys with its districts and national research, the agency has determined that HARs are less effective than DMS, and plans to change its HARs to static signs or small DMS. Nevada DOT determines remaining service life using a transition probability matrix (see **Supporting Documents**) to assess the change in asset condition rating.

Ramp Metering Systems

Illinois, Utah and Wisconsin DOTs gather data to conduct life cycle planning for ramp metering systems.

<u>Asset Condition</u>

Utah and Wisconsin DOTs reported having systems with multiple components:

- Utah:
  - Signal equipment.
  - Steel.
  - Controller.
  - Communications equipment.
  - Electronic and static signage.
  - Lighting.
  - Detection.
- Wisconsin:
  - Poles.
  - Signal heads.
  - Sensors/detection.
  - Controller.
  - Cabinet/components.

Utah and Wisconsin DOTs also track the life span of each component part. To determine the asset's overall condition, Utah DOT is implementing a system that rates each component on a scale of 1 to 5 (1 = dead/failed; 5 = excellent/new condition); the overall condition is the average of each component condition.

Methodologies Used to Assess Condition

To evaluate the ramp metering system condition, all three state DOTs use inspection reports; Utah and Wisconsin DOTs also use age-based assessment and engineering judgment along with annual or semiannual preventive maintenance visits (Utah) and maintenance history (Wisconsin). Table 15 summarizes survey responses.

Table 15. Ramp Metering System Condition Assessment Methodologies

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Illinois	X				
Utah	X	X	X	X	Annual/semiannual preventive maintenance visits by internal ITS staff.
Wisconsin	X	X	X	X	Maintenance history
Total	**3**	**2**	**2**	**2**	

Standard Categories in Condition Reports

Only Utah DOT applies standard categories in its condition reports:

- 1 = Failed (not working).
- 2 = Poor (damaged with intermittent failures).
- 3 = Fair (damaged, but still working; or working but obsolete).
- 4 = Good (Working condition, not new).
- 5 = Excellent/new.

Inspection Interval

Wisconsin DOT inspects ramp metering systems once a year. In Illinois, one district contracts maintenance inspections, which are conducted monthly for signal heads and quarterly for cabinets. Utah DOT's goal is to inspect systems semiannually, but the respondent noted that the agency is "fortunate" if these assets are inspected annually.

Preventive Maintenance Frequency

In Wisconsin, preventive maintenance of ramp metering systems is performed when the systems are inspected. Utah DOT's goal is to perform preventive maintenance semiannually, but the respondent noted that the agency is "fortunate" if it is performed annually. Illinois DOT does not have a preventive maintenance schedule.

Impact of Maintenance Activities on Service Life

The Wisconsin DOT respondent noted that regular maintenance is intended to extend the service life of ramp metering systems. The Utah DOT respondent reported that while in theory, well-maintained systems tend to last longer, the agency lacks data to support this belief and is trying to collect needed data.

Improving Ramp Metering System Condition

Utah DOT supports a time-based cycle to stay up-to-date on these systems and replace them before they fail so that operations appears seamless to the public. Wisconsin DOT attempts to improve the condition of ramp metering systems during preventive maintenance or when a repair is requested.

Estimated Service Life

The estimated service life of ramp metering systems is summarized below:

10-15 years	Illinois
15 years	Wisconsin
Other	Utah: Varies, depending on component

Influence of Industry Obsolescence on Estimated Service Life

Only Utah DOT reported that industry obsolescence influences the estimated service life of ramp metering systems. As an example, the respondent reiterated the agency's current effort of replacing analog CCTV cameras with digital units, even though the analog cameras are still functioning, because the analog units are no longer supported by the manufacturer.

Factors Affecting Remaining Service Life

Age, condition, engineering judgment, physical environment and usage are the key factors reported to affect the remaining service life of ramp metering systems. Another factor in Wisconsin is pavement detection. Table 16 summarizes survey results.

Table 16. Factors Affecting Remaining Service Life of Ramp Metering Systems

Factor	Illinois	Utah	Wisconsin	Total
Age	X	X	X	3
Condition		X	X	2
Engineering Judgment	X	X		2
Installation Date		X		1
Manufacturer Support of Device		X		1
Manufacturer Warranty		X		1
Mean Time Before Failure		X		1
Technology Advancements		X		1
Physical Environment		X	X	2
Physical Location		X		1
Usage		X	X	2
Other			Pavement detection	1

Replacement Interval

All three agencies replace ramp metering systems in connection with a roadway replacement or new construction project. None of the agencies considers replacement when one or more components fail. Table 17 summarizes survey results.

Table 17. Ramp Metering System Replacement Interval

State	End of Useful Life	Road Replacement/New Construction	Fails to Meet Performance Standards	Becomes Obsolete	No Longer Functions as Planned	Replacement Parts Not Available
Illinois		X				
Utah	X	X	X	X	X	X
Wisconsin		X				
Total	**1**	**3**	**1**	**1**	**1**	**1**

Calculations to Determine Remaining Service Life

Only Utah DOT described calculations to determine remaining service life. The agency bases its end-of-life replacement funding on the estimated percentage of each component that needs replacement each year multiplied by the cost to purchase and install each component.

Roadway Weather Information System

Nine states gather data to conduct life cycle planning for RWIS: Illinois, Maine, Michigan, Montana, Nevada, Pennsylvania, South Dakota, Utah and Virginia.

Asset Condition

Six states (Montana, Nevada, Pennsylvania, South Dakota, Utah and Virginia) reported having RWIS with multiple components. The Virginia DOT respondent noted that while these stations have multiple components, it assesses each station as a whole. Three states (South Dakota, Utah and Virginia) track the life span of each component part. In Pennsylvania, the RWIS program is administered by another division within the agency, not by Traffic Operations/ITS. These devices are tracked based on a multiyear contract.

To determine overall asset condition, South Dakota and Virginia DOTs consider the entire asset; no particular component dominates. Nevada DOT employs a deterioration model based on information from a transition probability matrix (see **Supporting Documents**). Utah DOT is currently implementing a new system that rates each component on a scale from 1 to 5 (1 = dead/failed; 5 = excellent/new condition). The overall condition is the average of each component condition. Table 18 summarizes survey responses.

Table 18. Description of RWIS Components

State	Multiple Components	Component Description	Tracks Part Life Span	Part That Determines Overall Condition
Montana	X	• Sensors • Cameras • RPU • Connectivity device		N/R
Nevada	X	• Inspections • Minor and major repairs • Replacements		Deterioration model based on a transition probability matrix (see **Supporting Documents**)

State	Multiple Components	Component Description	Tracks Part Life Span	Part That Determines Overall Condition
Pennsylvania	X	Program administered by another agency division		N/R
South Dakota	X	• Tower • Sensors • Controller • Communication	X	All (no particular component dominates)
Utah	X	• Various sensors (road temperature, visibility, snow depth, rain gauge, thermo-meter, anemometer) • Data logger • Solar panels and batteries • Communications equipment (fiber or modem) • CCTV camera (PTZ or fixed) • Tower crank	X	• Implementing new system that rates each component on a scale of 1 to 5 (1 = dead/failed; 5 = excellent/new condition). • Overall condition: Average of each component condition.
Virginia	X	N/R	X	Overall working of the system.

N/R No response.

Methodologies Used to Assess Condition

To evaluate RWIS condition, six states use inspection reports, five states use age-based assessments, and four states use engineering judgment. Other assessment methodologies include performance (South Dakota) and annual maintenance visits (Maine and Utah). In addition to following manufacturer's recommendations, Nevada DOT is tracking work orders in an asset management program that will be used to develop a performance-based condition reporting system. Table 19 summarizes survey responses.

Table 19. RWIS Condition Assessment Methodologies

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Illinois	X				
Maine		X		X	Annual maintenance visit.
Michigan	X	X	X		
Montana	X	X	X		
Nevada				X	• Primarily manufacturer's recommended life. • Tracking work orders in an asset management program that will be used to develop a performance-based condition reporting system.
South Dakota	X	X		X	Performance.
Utah	X	X	X	X	Annual/semiannual preventive maintenance visits by internal ITS staff.
Virginia	X		X		
Total	**6**	**5**	**4**	**5**	

Standard Categories in Condition Reports

Nevada, Utah and Virginia DOTs apply standard categories in their condition reports:

Nevada: Good, low risk, medium risk and high risk.

Utah:

- 1 = Failed (not working).
- 2 = Poor (damaged with intermittent failures).
- 3 = Fair (damaged, but still working; or working but obsolete).
- 4 = Good (working condition, not new).
- 5 = Excellent/new.

Virginia: Each component.

Inspection Interval

RWIS inspections are conducted annually in four states. Montana and Virginia DOTs inspect systems as needed for repairs. Utah DOT's goal is to inspect devices semiannually, but the respondent noted that the agency is "fortunate" if these assets are inspected annually. Nevada DOT's inspection interval is based on asset type; the agency uses four categories: inspections, minor repairs, major repairs and replacements. Table 20 summarizes survey responses.

Table 20. Inspection Interval for RWIS

State	Annually	Other	Description
Maine	X		
Michigan	X		
Montana	X	X	As needed for repairs
Nevada		X	• Based on type of asset • Four categories: ○ Inspections ○ Minor repairs ○ Major repairs ○ Replacements
South Dakota	X		
Utah		X	Goal: Semiannually for most devices, but "fortunate" if conducted annually
Virginia		X	As needed for repairs
Total	**4**	**4**	

Preventive Maintenance Frequency

Five of seven states perform preventive maintenance on RWIS once a year. Utah DOT's goal is to perform preventive maintenance semiannually, but the respondent noted that the agency is "fortunate" if it is performed annually. Table 21 summarizes survey responses.

Table 21. Preventive Maintenance Frequency for RWIS

State	Annually	Other	Description
Illinois	X		
Maine	X		
Michigan	X		
Montana	X		
Nevada		X	• Based on type of asset • Four categories: ○ Inspections ○ Minor repairs ○ Major repairs ○ Replacements
South Dakota	X		
Utah		X	Goal: Semiannually for most devices, but "fortunate" if conducted annually
Virginia		X	When the station has an issue
Total	**5**	**3**	

Impact of Maintenance Activities on Service Life

Maine, Utah and Virginia DOTs reported that performing maintenance on RWIS is intended to extend the asset's service life. The Utah DOT respondent noted that the agency is currently trying to collect data to support this belief. In South Dakota, maintenance addresses aspects of the asset's physical condition, such as cabling and mounting. Nevada DOT is planning to use a performance-based approach to evaluate the asset's remaining life that will eventually tie in to its 10-year maintenance asset funding for investments.

Improving RWIS Condition

Michigan, South Dakota and Virginia DOTs attempt to improve the condition of RWIS when assets are not functioning as intended or when components fail. South Dakota DOT designs, integrates, installs and maintains its own RWIS installations, which makes most component replacements straightforward. Other circumstances for improving RWIS condition include during annual maintenance visits (Maine) or as connectivity improvements become available (Montana). Table 22 summarizes survey responses.

Table 22. Determining When Agency Improves RWIS Condition

Topic	State	Description
Annual Maintenance	Maine	Annual maintenance visit.
Functioning Issues	Michigan, South Dakota, Virginia	*Michigan*: When asset is not functioning as intended. *South Dakota*: • The agency designs, integrates, installs and maintains its own RWIS installations. • Failed components are replaced or repaired to maintain operation. • Short of complete destruction of the tower and installation, component replacement is straightforward. *Virginia*: When the station is not functioning as intended.

Topic	State	Description
Technology Advances	Montana	Improvements in connectivity become available.
Other	Nevada, Utah	*Nevada*: Four condition states: • **Good**: Less than 80% of asset life (based on manufacturer-recommended device service life) has been used for 50% of the network. • **Low risk**: 80%-100% of asset life has been used for 50% of the network. • **Medium risk**: 100%-125% of asset life has been used for 50% of the network. • **High risk**: More than 125% of the asset life has been used for 50% of the network. *Utah*: Goal is to replace assets before they fail.

Estimated Service Life

The estimated service life of RWIS is summarized below:

7-10 years	Virginia
10 years	Maine, Montana.
10-15 years	Illinois
15 years	Michigan
20+ years	South Dakota
Other	*Nevada*: As part of its TAMP, the agency uses a 10-year maintenance asset budget that is distributed annually for each of the devices recorded. *Utah*: Varies by component, but average of 10 years for system.

Influence of Industry Obsolescence on Estimated Service Life

Four agencies reported that industry obsolescence influences the estimated service life of RWIS. Virginia DOT has so many RWIS stations that the agency "just [tries to] keep them maintained and working." The Montana DOT respondent noted that obsolescence of sensors or modems affect duration of use. The Utah DOT respondent again referred to the agency's current effort of replacing analog CCTV cameras with digital units; even though the analog cameras are still functioning, they are no longer supported by the manufacturer. The Nevada DOT respondent reported that industry obsolescence does not specifically impact an asset's estimated service life because the agency uses a weighted factor table based on the health of that device.

Factors Affecting Remaining Service Life

Table 23 identifies the factors that affect the remaining service life of RWIS.

Table 23. Factors Affecting Remaining Service Life of RWIS

State	Age	Condition	Engineering Judgment	Installation Date	Manufacturer Support	Manufacturer Warranty	MTBF*	Technology Advances
Illinois	X	X						

State	Age	Condition	Engineering Judgment	Installation Date	Manufacturer Support	Manufacturer Warranty	MTBF*	Technology Advances
Maine		X						
Michigan	X		X		X			
Montana	X	X	X		X			X
Nevada								
South Dakota		X						
Utah	X	X	X	X	X	X	X	X
Virginia	X	X						
Total	**5**	**6**	**3**	**1**	**3**	**1**	**1**	**2**

* MTBF: mean time before failure.

Table 23. Factors Affecting Remaining Service Life of RWIS, Continued

State	Physical Environment	Physical Location	Usage	Other	Description
Illinois					
Maine					
Michigan					
Montana	X				
Nevada				X	Additional factors: • Maintenance costs per unit • Asset condition • Network growth rate • Fraction of the network that will receive each maintenance activity based on its condition • Weight factors associated with each condition for calculating the health index Inputs provided to transition probability matrix (see **Supporting Documents**). The number of years from one condition state to another is based on the time it takes for 50% of devices in one condition state to deteriorate to the next condition state.
South Dakota	X				
Utah	X	X	X		
Virginia	X	X	X		
Total	**4**	**2**	**2**	**1**	

Replacement Interval

Agencies most frequently reported replacing RWIS at the end of its useful life (five states), in connection with a roadway replacement or new construction project (five states) and when the asset no longer functions as originally intended (five states). South Dakota DOT has not completely replaced the assets since adopting the current design. The agency replaces components as necessary, but the design is modular and can evolve with technological advances. Table 24 summarizes survey responses.

Table 24. RWIS Replacement Interval

State	End of Useful Life	Road Replacement/New Construction	Fails to Meet Performance Standards	Obsolescence	No Longer Functions as Planned	Component Fails	Replacement Parts Not Available	Other
Illinois	X				X			
Maine	X							
Michigan		X	X		X		X	
Montana	X	X		X	X	X	X	
Nevada								Funding availability
South Dakota	X	X						As needed
Utah	X	X	X	X	X		X	
Virginia		X	X		X	X		
Total	**5**	**5**	**3**	**2**	**5**	**2**	**3**	

Calculations to Determine Remaining Service Life

To determine remaining service life, Nevada DOT uses a transition probability matrix to assess the change in asset condition rating (see **Supporting Documents**). Utah DOT bases its end-of-life replacement funding on the estimated percentage of each component that needs replacement each year multiplied by the cost to purchase and install each component.

Traffic Census Stations

Four states gather data to conduct life cycle planning for traffic census stations: Illinois, Pennsylvania, South Dakota and Wisconsin.

Asset Condition

Traffic census stations in Pennsylvania, South Dakota and Wisconsin have multiple components. South Dakota and Wisconsin DOTs track the life span of each component part. Pennsylvania DOT's traffic counter program is managed by another division that works directly with the agency's Planning and Programming division. Tracking of these assets is based upon a multiyear contract. South Dakota DOT evaluates the asset's electronics to determine overall asset condition. Table 25 summarizes survey responses.

Table 25. Description of Traffic Census Station Components

State	Multiple Components	Component Description	Tracks Part Life Span	Part That Determines Overall Condition
Pennsylvania	X	Program administered by another agency division		N/R
South Dakota	X	• Cabinets • Electronics	X	Electronics
Wisconsin	X	• Poles	X	N/R

State	Multiple Components	Component Description	Tracks Part Life Span	Part That Determines Overall Condition
		• Solar systems • Loops • Nonintrusive detection • Piezos • Traffic counters		

Methodologies Used to Assess Condition

Inspection reports are used by two states (Illinois and South Dakota) to evaluate traffic census station condition, followed by age-based assessments (Wisconsin) and engineering judgment (Wisconsin). South Dakota also considers performance in these assessments. Table 26 summarizes survey responses.

Table 26. Traffic Census Station Condition Assessment Methodologies

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Illinois	X				
South Dakota	X			X	Performance
Wisconsin		X	X		
Total	**2**	**1**	**1**	**1**	

Standard Categories in Condition Reports

None of the agencies applies standard categories in their condition reports.

Inspection Interval

Inspection intervals and practices vary among responding agencies:

- Once a year:
    - *Illinois*: For cabinets and detection devices (such as loops, magnetometer, radar and Bluetooth). The respondent added that one district contracts maintenance inspections.
    - *South Dakota*.
- Other:
    - *Wisconsin*: Information is downloaded daily. The agency performs repairs if data is missing. Calibrations are performed yearly.

Preventive Maintenance Frequency

Only South Dakota reported on the frequency of preventive maintenance, which is conducted once a year.

Impact of Maintenance Activities on Remaining Service Life

The Wisconsin DOT respondent noted that performing system and component maintenance is intended to extend the service life of the asset.

Improving Traffic Census Station Condition

Both South Dakota and Wisconsin DOTs repair assets as needed (for example, in Wisconsin, when a sensor, battery or other part fails).

<u>Estimated Service Life</u>

The estimated service life of traffic census stations is summarized below:

10 years	South Dakota, Wisconsin
10-15 years	Illinois

Influence of Industry Obsolescence on Estimated Service Life

Respondents from both South Dakota and Wisconsin DOTs reported that industry obsolescence influences the asset's estimated service life. The South Dakota DOT respondent noted that if vendor support is no longer available, equipment must be upgraded. The Wisconsin DOT respondent noted that without this support, traffic counters and modems must be upgraded.

Factors Affecting Remaining Service Life

Table 27 identifies the factors that affect the remaining service life of traffic census stations.

Table 27. Factors Affecting Remaining Service Life of Traffic Census Station

State	Age	Condition	Engineering Judgment	Manufacturer Support	Physical Environment	Physical Location	Other
Illinois		X					
South Dakota	X	X		X			Performance
Wisconsin	X	X	X		X	X	
Total	**2**	**3**	**1**	**`**	**1**	**1**	**1**

Replacement Interval

Agencies most frequently reported replacing traffic census stations in connection with a roadway replacement or new construction project and when the asset no longer functions as originally intended (two states each). Table 28 summarizes survey responses.

Table 28. Traffic Census Station Replacement Interval

State	End of Useful Life	Road Replacement/ New Construction	Fails to Meet Performance Standards	No Longer Functions as Planned	Component Fails
Illinois				X	X
South Dakota	X	X		X	
Wisconsin		X	X		
Total	**1**	**2**	**1**	**2**	**1**

Calculations to Determine Remaining Service Life

None of the agencies described calculations used to determine remaining service life.

Traffic Monitoring Detection Stations

Five states gather data to conduct life cycle planning for traffic monitoring detection stations: Illinois, Michigan, South Dakota, Utah and Wisconsin.

Asset Condition

Traffic monitoring detection stations in three states (South Dakota, Utah and Wisconsin) have multiple components. These same three states track the life span of each component part. To determine overall asset condition, South Dakota DOT considers the asset's electronics. Utah DOT is currently implementing a new system that rates each component on a scale from 1 to 5 (1 = dead/failed; 5 = excellent/new condition). The overall condition is the average of each component condition. Table 29 summarizes survey responses.

Table 29. Description of Traffic Monitoring Detection Station Components

State	Multiple Components	Component Description	Tracks Part Life Span	Part That Determines Overall Condition
South Dakota	X	• Cabinets • Electronics • Sensors	X	Electronics
Utah	X	• Detection devices • Solar panels and batteries • Controller • Communications equipment	X	• Implementing new system that rates each component on a scale from 1 to 5 (1 = dead/failed; 5 = excellent/new condition). • Overall condition: Average of each component condition.
Wisconsin	X	• Poles • Detectors • Loops • Solar power systems • Cabinets/equipment	X	N/R

N/R No response.

Methodologies Used to Assess Condition

All five states use inspection reports to evaluate traffic monitoring detection station condition. Michigan, Utah and Wisconsin DOTs also use age-based assessments and engineering judgment. Additional methodologies include performance (South Dakota) and maintenance history (Wisconsin). Table 30 summarizes survey responses.

Table 30. Traffic Monitoring Detection Station Assessment Methodologies

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Illinois	X			X	One district contracts maintenance inspections: annual for cabinets and detection devices (loops, magnetometer, radar, Bluetooth)
Michigan	X	X	X		
South Dakota	X			X	Performance

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Utah	X	X	X	X	Annual/semiannual preventive maintenance visits by internal ITS staff.
Wisconsin	X	X	X	X	Maintenance history
Total	**5**	**3**	**3**	**4**	

Standard Categories in Condition Reports

Utah DOT applies standard categories in its condition reports.

- 1 = Failed (not working).
- 2 = Poor (damaged with intermittent failures).
- 3 = Fair (damaged, but still working; or working but obsolete).
- 4 = Good (working condition, not new).
- 5 = Excellent/new.

Inspection Interval

Inspection intervals and practices used by responding agencies are summarized below:

- Once a year:
  - Illinois (cabinets and detection devices such as loops, magnetometer, radar and Bluetooth). One district contracts maintenance inspections.
  - Michigan.
  - South Dakota.
  - Wisconsin.
- Other:
  - *Utah*: Goal is semiannually for most devices, but "fortunate" if conducted annually.

Preventive Maintenance Frequency

Preventive maintenance is conducted at the following intervals:

- Once a year: South Dakota.
- Twice a year: Michigan.
- None: Illinois.
- Other:
  - *Utah*: Goal is semiannually for most devices, but "fortunate" if conducted annually.
  - *Wisconsin*: Inspection and preventive maintenance occur at the same time.

Impact of Maintenance Activities on Remaining Service Life

Respondents from Utah and Wisconsin noted that maintenance activities are intended to extend the remaining service life of traffic monitoring detection stations. The Utah DOT respondent added that the agency is currently trying to collect data to support this belief. In South Dakota, components are replaced or repaired as necessary, and in Michigan, maintenance history is reviewed when assessing the asset.

Improving Traffic Monitoring Detection Station Condition

South Dakota and Wisconsin DOTs attempt to improve the asset's condition as needed. In South Dakota, components are replaced or repaired as necessary, and in Wisconsin, issues are addressed when the agency receives a request for repair or during preventive maintenance. Michigan DOT evaluates conditions at or near the end of useful life. Utah DOT supports a time-based cycle to keep on top of assets and replace them before they fail.

<u>Estimated Service Life</u>

The estimated service life of traffic monitoring detection stations is summarized below:

5 years	Michigan
6-10 years	Utah
9 years	Wisconsin
10 years	South Dakota
10-15 years	Illinois

Influence of Industry Obsolescence on Estimated Service Life

Respondents from South Dakota, Utah and Wisconsin DOTs reported that industry obsolescence influences the asset's estimated service life. The South Dakota DOT respondent noted that if vendor support is no longer available, equipment must be upgraded. The Wisconsin DOT respondent noted that service life is impacted by parts availability and new technologies. The Utah DOT respondent again referred to the agency's current effort of replacing analog CCTV cameras with digital units; even though the analog cameras are still functioning, they are no longer supported by the manufacturer.

Factors Affecting Remaining Service Life

Table 31 identifies the factors that affect the remaining service life of traffic monitoring detection stations.

Table 31. Factors Affecting Remaining Service Life of Traffic Monitoring Detection Stations

Factor	Illinois	Michigan	South Dakota	Utah	Wisconsin	Total
Age		X	X	X	X	**4**
Condition	X	X	X	X	X	**5**
Engineering Judgment		X		X		**2**
Installation Date				X		**1**
Manufacturer Support of Device		X		X		**2**
Manufacturer Warranty				X		**1**
Mean Time Before Failure				X		**1**
Technology Advances				X	X	**2**
Physical Environment				X		**1**
Physical Location				X		**1**
Usage				X		**1**
Other			Performance			**1**

Replacement Interval

Table 32 summarizes the intervals at which agencies replace traffic monitoring detection stations.

Table 32. Traffic Monitoring Detection Station Replacement Interval

State	End of Useful Life	Road Replacement/ New Construction	Failure to Meet Performance Standards	Obsolescence	No Longer Functions as Planned	Component Fails	Replacement Parts Not Available
Illinois					X	X	
Michigan	X		X		X		X
South Dakota	X	X			X		
Utah	X	X	X	X	X		X
Wisconsin	X	X	X		X		
Total	**4**	**3**	**3**	**1**	**5**	**1**	**2**

Calculations to Determine Remaining Service Life

Utah DOT provided information about determining remaining service life. The agency bases its end-of-life replacement funding on the estimated percentage of each component that needs replacement each year multiplied by the cost to purchase and install each component.

Traffic Signals

Six states gather data to conduct life cycle planning for traffic signals: Illinois, Montana, Pennsylvania, Utah, Virginia and Wisconsin

Asset Condition

All six states reported traffic signals with multiple components. Utah, Virginia and Wisconsin DOTs track the life span of each component part. To determine overall asset condition, respondents described specific parts such as the signal controller (Montana), signal head (Pennsylvania) and structure (Pennsylvania). Virginia DOT assesses all parts together as a whole. Utah DOT is currently implementing a new system that rates each component on a scale from 1 to 5 (1 = dead/failed; 5 = excellent/new condition). The overall condition is the average of each component condition. Table 33 summarizes survey responses.

Table 33. Description of Traffic Signal Components

State	Multiple Components	Component Description	Tracks Part Life Span	Part That Determines Overall Condition
Illinois	X	• Structures • Mast arms • Pole • Signal heads • Controllers • Cabinets		N/R

State	Multiple Components	Component Description	Tracks Part Life Span	Part That Determines Overall Condition
Montana	X	• Signal controllers • Detection • Preemption equipment		Signal controller
Pennsylvania	X	• Signal head • Structure • Cabinet • Controller • Conflict monitor		• Signal head • Structure
Utah	X	• Signal equipment • Controller • Cabinet • Communications equipment • Steel • Detection equipment	X	• Implementing new system that rates each component on a scale from 1 to 5 (1 = dead/failed; 5 = excellent/new condition). • Overall condition: Average of each component condition.
Virginia	X	Many	X	All parts together as a whole
Wisconsin	X	• Poles • Signal heads • Controllers • Multi-meter unit (MMU) • Nonintrusive detection • Loops • Pedestrian pushbuttons • Luminaires • Battery backups • Cabinet/components	X	N/R

N/R No response.

Methodologies Used to Assess Condition

To evaluate traffic signal condition, all six states use inspection reports and age-based assessments. In addition, Illinois, Montana, Utah, Virginia and Wisconsin DOTs rely on engineering judgment. Preventive maintenance visits (Utah), maintenance calls (Virginia) and maintenance history (Wisconsin) are also used. Table 34 summarizes survey responses.

Table 34. Traffic Signal Condition Assessment Methodologies

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Illinois	X	X	X		
Montana	X	X	X		
Pennsylvania	X	X			
Utah	X	X	X	X	Annual/semiannual preventive maintenance visits by internal ITS staff.
Virginia	X	X	X	X	Maintenance calls

State	Inspection Reports	Age Based Assessment	Engineering judgment	Other	Description
Wisconsin	X	X	X	X	Maintenance history.
Total	**6**	**6**	**5**	**3**	

Standard Categories in Condition Reports

Pennsylvania, Utah and Virginia DOTs apply standard categories in their condition reports:

- Pennsylvania:
    - 1 = Should be replaced.
    - 2 = Continue evaluation.
    - 3 = New.
- Utah:
    - 1 = Failed (not working).
    - 2 = Poor (damaged with intermittent failures).
    - 3 = Fair (damaged, but still working; or working but obsolete).
    - 4 = Good (working condition, not new).
    - 5 = Excellent/new.
- Virginia:
    - Control cabinet.
    - Cable.
    - Pole and foundations.
    - Signal heads.
    - Backplates.

Inspection Interval

Table 35 presents the inspection intervals of traffic signals. Note: Pennsylvania DOT does not own traffic signals; local governments regulate inspections.

Table 35. Inspection Interval for Traffic Signals

State	Monthly	Annually	Other	Description
Illinois			X	*Daily*: Closed-loop systems (monitored remotely for error events) *Monthly:* Patrol (drive-by) inspection *Annually*: • Structures, mast arms and poles • Signals interconnected with a railroad crossing • Relamp signals still using incandescent lamps *Every other year*: Conflict monitors (MMU)
Montana	X			
Pennsylvania			X	Inspection regulated by local government (Pennsylvania DOT does not own the signal).
Utah			X	Goal: Semiannually for most devices, but “fortunate” if conducted annually.
Virginia		X	X	Maintenance calls
Wisconsin		X		
Total	**1**	**2**	**4**	

Preventive Maintenance Frequency

Table 36 identifies the preventive maintenance frequency of traffic signals. Note: Pennsylvania DOT does not own traffic signals; local governments regulate preventive maintenance.

Table 36. Preventive Maintenance Frequency for Traffic Signals

State	Annually	Other	Description
Illinois		X	*Daily*: Closed-loop systems (monitored remotely for error events) *Monthly:* Patrol (drive-by) inspection *Annually*: • Signals interconnected with a railroad crossing • Relamp signals still using incandescent lamps *Every other year*: Conflict monitors (MMU)
Montana	X		
Pennsylvania		X	Preventive maintenance is regulated by local government (Pennsylvania DOT does not own the signal).
Utah		X	Goal: Semiannually for most devices, but “fortunate” if conducted annually.
Virginia	X		
Wisconsin		X	Inspection and preventive maintenance occur at the same time
Total	**1**	**4**	

Effect of Maintenance Activities on Remaining Service Life

Respondents from Utah, Virginia and Wisconsin DOTs noted that maintenance activities are intended to extend the remaining service life of traffic signals. The Utah DOT respondent added that the agency is currently trying to collect data to support this belief. The Pennsylvania DOT respondent noted that municipalities evaluate remaining service life when they perform maintenance.

Improving Traffic Signal Condition

Pennsylvania, Virginia and Wisconsin DOTs attempt to improve a traffic signal’s condition when the asset is in need of repair. Wisconsin DOT also addresses issues during preventive maintenance, and Virginia DOT attempts to improve the asset’s condition during construction projects, for system upgrades on a corridor, when technology is outdated and when more functionality is needed. The availability of an advanced signal controller or increased vehicle detection needs prompt Montana DOT to improve the asset’s condition. Utah DOT supports a time-based cycle to keep on top of assets and replace them before they fail.

Estimated Service Life

The estimated service life of traffic signals is summarized below:

8-10 years	Virginia
10-15 years	Pennsylvania

25 years	Wisconsin
30 years	Montana
Other	Varies based on component: Illinois, Utah

Influence of Industry Obsolescence on Estimated Service Life

Respondents from Montana, Pennsylvania, Utah and Virginia DOTs reported that industry obsolescence influences the asset's estimated service life. In Virginia, service life is impacted if a particular signal can no longer handle the demands of a complicated intersection. If new technology is available to Pennsylvania DOT, the agency attempts to evaluate as many devices as possible. Montana DOT upgrades controllers as a result of obsolescence. The Utah DOT respondent again referred to the lack of manufacturer support for analog CCTV cameras, which the agency is replacing with digital units even though the analog cameras are still functioning.

Factors Affecting Remaining Service Life

Table 37 identifies the factors that affect the remaining service life of traffic signals.

Table 37. Factors Affecting Remaining Service Life of Traffic Signals

Factor	Illinois	Montana	Pennsylvania	Utah	Virginia	Wisconsin	Total
Age	X		X	X	X	X	**5**
Condition	X	X	X	X	X	X	**6**
Engineering Judgment	X	X		X	X	X	**5**
Installation Date			X	X			**2**
Manufacturer Support of Device	X	X	X	X	X		**5**
Manufacturer Warranty				X	X		**2**
Mean Time Before Failure				X			**1**
Technology Advances		X	X	X	X	X	**5**
Physical Environment		X	X	X	X		**4**
Physical Location		X	X	X	X		**4**
Usage				X		X	**2**

Replacement Interval

Table 38 summarizes the intervals at which agencies replace traffic signals.

Table 38. Traffic Signal Replacement Interval

State	End of Useful Life	Road Replacement/New Construction	Fails to Meet Performance Standards	Obsolescence	No Longer Functions as Planned	Component Fails	Replacement Parts Not Available
Illinois	X	X		X	X	X	X
Montana		X	X		X	X	X
Pennsylvania		X	X		X	X	X
Utah	X	X	X	X	X		X
Virginia		X	X		X	X	X
Wisconsin		X					
Total	**2**	**6**	**4**	**2**	**5**	**4**	**5**

Calculations to Determine Remaining Service Life

None of the agencies described calculations their agencies use to determine remaining service life.

Other Life Cycle Planning Practices

Additional Devices in ITS Asset Inventory

Three agencies support additional devices in their ITS asset inventory:

- *Michigan*: all components, such as supports, power supply, Ethernet switches and roadside units.
- *Utah*: Fiber optic communications systems, including hubs, switches, fiber cable, splice enclosures, junction boxes, air conditioning units at hubs, uninterruptible power supply, batteries and gator patches.
- *Wisconsin*: Portable CMS, portable traffic cameras and network communication huts.

ITS Asset Classification by Significance

Pennsylvania and Virginia DOTs categorize ITS assets in terms of their significance to agency operations. Statewide, Pennsylvania DOT currently focuses on CCTV, DMS, signals and HAR. The respondent noted that additional devices may be captured at the district level. In Virginia, operation technology is, in many cases, life safety items.

Central Repository of ITS Asset Data

Nine agencies maintain or are developing a central repository of ITS asset data:

- *Maine*: MATS (Managed Assets for Transportation Systems). The agency partners with New Hampshire and Vermont transportation agencies on this system.
- *Michigan*: Asset Management Database (AMD), a web-based system.
- *Montana*: Data included in the agency's maintenance management system.
- *Nevada*: Nevada Data Exchange.
- *Pennsylvania*: The agency is migrating the ITS device inventory system into its Traffic Signal Asset Management System (TSAMS) tool. However, this has not evolved into a full asset management system with life cycle analysis capabilities.

- *South Dakota*: Asset management system exclusively for ITS devices.
- *Utah*:
  - Asset Inventory Management System (AIMS), developed internally, manages inventory and work orders.
  - WhatsUp Gold, a communications monitoring system that tracks the number of devices communicating.
- *Virginia*: The agency is currently developing a central repository.
- *Wisconsin*: VUEWORKS software.

ITS Data Repository and Agency TAMS

In four states, the ITS data repository is separate from and does not interface with the agency's overall transportation asset management system (TAMS). One state has an ITS data repository that is separate from but does interface with that agency's TAMS; one state has an ITS data repository that is part of the agency's TAMS; and one state has an ITS data repository in which some of the data is in the agency's TAMS and some is separate, and the two do not interface. Table 39 summarizes survey responses.

Table 39. Use of an ITS Data Repository

State	No ITS Data Repository	Repository Separate From/Does Not Interface With TAMS	Repository Separate From But Interfaces With TAMS	Repository Part of TAMS	Other	Description
Illinois	X					
Maine			X			
Michigan		X				
Montana				X		
Nevada					X	Repository will eventually interface with statewide asset management platform.
Pennsylvania		X				
South Dakota		X				
Utah					X	Systems are used to help manually generate data needed for TAMS on an annual basis.
Virginia					X	Some data is in the agency's TAMS; some is separate. The two do not interface.
Wisconsin		X				
Total	**1**	**4**	**1**	**1**	**3**	

Use of Performance Measures

Utah DOT currently uses performance measures to track ITS assets. The agency tracks inventory growth, percentage of devices communicating to its Traffic Operations Center (communications uptime) and traffic signal location condition (good, fair or poor) (see *Related Resource* below). The agency is currently overhauling its performance measures for ITS and traffic signals.

Pennsylvania DOT only uses a monthly uptime calculation with a minimum requirement of 95% uptime. Maine and Nevada DOTs are currently developing performance measures to track ITS assets. Michigan DOT does not use performance measures but plans to in the future.

In Virginia, signals are tracked by visits to individual signal locations.

Related Resource:

Infrastructure Performance Measures, Utah Department of Transportation, undated.
https://www.udot.utah.gov/strategic-direction/preserve-infrastructure.html
From the web site:

- *ITS*: This measure shows the percentage of ITS field devices communicating with the Traffic Operations Center (including CCTV, VMS, [t]raffic [s]ignals, [r]amp [m]eters, [t]raffic [m]onitoring [s]ensors).
- *Signal Condition*: These values represent the percent of [Utah] DOT traffic signals that are in good, average and poor condition.

Assessment and Recommendations

Successes

Life cycle planning practices for ITS assets has enhanced access to funding and other resources for Utah and Wisconsin DOTs. Utah DOT has received dedicated annual funding for ITS and traffic signal end-of-life replacements. Wisconsin DOT is better able to identify and justify resources needed for replacing equipment. These practices have given Maine DOT a high uptime level for its devices because the agency now has a replacement schedule that feeds its annual work plan requests.
Respondents from six states (Illinois, Michigan, Nevada, Pennsylvania, South Dakota and Virginia) noted that their agencies are still developing life cycle planning practices, making it too soon to report on successes. Additional information from three agencies follows:

- Illinois DOT is still attempting to collect baseline asset data.
- Michigan DOT expects "a lot of success" once its device modernization plan is implemented.
- After using its asset management system for one year, South Dakota DOT can track information on both installations and components, which may move among installations.

Challenges

Respondents reported a number of challenges encountered when conducting life cycle planning for ITS assets:

- *Data*:
  - Baseline asset data collection (Illinois).
  - Centralized data collection (Virginia).
  - Accurate asset data on devices (Wisconsin).

- *Device-related issues*:
    - Device tracking (Pennsylvania). Device tracking is assigned to multiple divisions within the agency.
    - Device failure (South Dakota). ITS assets typically don't deteriorate continuously, but often fail quickly, making prediction more challenging. A more probabilistic approach is needed.
- *Coordination* (design and construction) (Michigan).
- *Maintenance history* (Pennsylvania). Capturing this information is challenging.
- *Central system development* to track repair costs and device condition status (Maine).
- *Cybersecurity* (Virginia).
- *Funding* (Michigan).
- *Staffing* (Utah). Sufficient internal personnel and contractors are needed.
- *Unfamiliarity* (Nevada). The agency is trying to include life cycle planning as performance-based practices into its maintenance agreements.

Recommendations

Other agencies seeking to improve life cycle planning practices for ITS assets could consider the following steps:

Maine DOT:

- Develop a central system to track repair costs and device condition status.
- Create a replacement schedule that feeds annual work plan requests.

Michigan DOT:

- Develop an accurate and up-to-date inventory.
- Improve coordination.
- Conduct more frequent inspection (structural).

Montana DOT:

- Ensure a budget for future replacements.

Nevada DOT:

- Include life cycle planning practices into the state's certified TAMP.
- Develop an ITS life cycle costing analysis tool.
- Develop an asset management program.

Pennsylvania DOT:

- Develop a standard maintenance history evaluation and record keeping module.
- Unify what division or agency is responsible for tracking all devices.

South Dakota DOT:

- Acquire and use an ITS asset management system.
- Track both installations and components.

Utah DOT:

- Obtain high-quality data. Agencies must have good data to show asset status and needs.

- Ensure constant communication with decision-makers both for funding purposes and support for personnel needs.
- Start by conducting an inventory to learn what is currently available.

Wisconsin DOT:

- Develop and use a system that tracks asset data and maintenance history.
- Develop a policy or process that outlines the expected service life for various ITS devices and asset data maintenance.
- Properly resource efforts for asset management and life cycle replacement efforts.

Supporting Documents

Below are resources provided by survey respondents about their agencies' ITS asset life cycle planning practices.

Nevada

Fully-Compliant Transportation Asset Management Plan, Nevada Department of Transportation, April 2019.
https://www.dot.nv.gov/home/showdocument?id=16759
Life cycle planning considerations for ITS assets are addressed in Chapter 4 beginning on page 47 of the PDF. The discussion explains the agency's use of a good/low risk/medium risk/high risk condition rating system based on a device manufacturer's recommended service life and the use of a transition probability matrix to model deterioration. Appendix B (page 105 of the PDF) details the key assumptions used in modeling life cycle performance for six ITS assets: CCTV, DMS, flow detectors, highway activity reporting devices, ramp meters and RWIS.

ITS Life Cycle Costing Investment Tool, Version 7, Nevada Department of Transportation, 2020.
(Caltrans staff, please copy and paste the text below to download the Nevada DOT ITS Life Cycle Costing Investment spreadsheet. For anyone external to Caltrans, please contact the customer at the beginning of the report to access the spreadsheet.)
https://drisi.onramp.dot.ca.gov/downloads/drisi/files/Preliminary-Investigations/Nevada-DOT-ITS-Life-Cycle-Costing-Investment-Tool.xlsx
Nevada DOT's four condition states (good, low risk, medium risk and high risk) are presented in this spreadsheet tool that quickly estimates the deterioration rates and maintenance costs of ITS assets.

Oregon

Fix-It Program Overview: Funding Scenarios for 10-Year Strategic Plan and 24-27 STIP, Statewide Project Delivery Branch, Oregon Department of Transportation, April 17, 2020.
(Caltrans staff, please copy and paste the text below to download the Oregon DOT Fix-It Program's strategies. For anyone external to Caltrans, please contact the customer at the beginning of the report to access the document.)
https://drisi.onramp.dot.ca.gov/downloads/drisi/files/Preliminary-Investigations/Oregon-DOT-Fix-It-Programs-Funding-Scenarios-and-Strategies.pdf
This document includes a description of Oregon DOT's operations program (beginning on page 28 of the document) along with current assumed life spans for assets.

Wisconsin

Life Cycle of Intelligent Transportation Systems (ITS) Field Devices Statewide ITS Field Device Maintenance and Support Services, Technical Memorandum, Wisconsin Department of Transportation, November 16, 2020.
(Caltrans staff, please copy and paste the text below to download the Wisconsin DOT tech memo. For anyone external to Caltrans, please contact the customer at the beginning of the report to access the document.)
https://drisi.onramp.dot.ca.gov/downloads/drisi/files/Preliminary-Investigations/Wisconsin-DOT-LCC-ITS-Tech-Memo.pdf
From the introduction: This memorandum documents the research and review conducted to gather and explore information on typical life expectancy for ITS field devices in order to determine useful service life and average replacement cycles. However, it should be noted that there are two (2) key ongoing system activities, routine (preventative) and remedial (standard and emergency) maintenance, that still need to be conducted and are a key part of the replacement process to achieve an average life-cycle for ITS field devices. In addition, the life-cycle process also needs to factor in and consider such things as geographic area (e.g., inclement weather) along with the degradation and obsolescence of technological components.

Agencies Not Conducting ITS Asset Life Cycle Planning

Transportation agencies from six states do not gather data to conduct life cycle planning of ITS assets: Arkansas, Idaho, Massachusetts, New Jersey, North Dakota and Oklahoma.

Four of these agencies are considering adopting a life cycle planning model or methodologies:

- Massachusetts DOT is considering an expansion of its asset management systems.
- New Jersey DOT is currently discussing adopting a model or methodologies.
- North Dakota DOT is working to establish a dedicated maintenance budget for ITS devices so that it can better track the replacement costs and life cycle costs of devices. (Currently each district is responsible for maintaining, repairing or replacing the devices, which makes it difficult for North Dakota DOT to track device condition.)
- Oklahoma DOT would adopt a model or methodology if it had more guidance or information.

Arkansas DOT and Idaho Transportation Department do not have plans to adopt a model or methodologies for assessing ITS assets. However, Idaho Transportation Department is currently collecting date information when a new ITS device is installed or replaced so that future information about the age of the device will be available.

Related Research and Resources

A literature search of domestic and international in-progress and published research examined life cycle planning for ITS assets. The literature search also sought information about ITS performance measures and data archiving systems. Findings from this literature search are presented below in the following topic areas:

- National research and resources.
- State research and resources.
- International research and resources.
- Related resources.

National Research and Resources

Managing TMS Assets and Resources, National Operations Center of Excellence, 2021.
https://www.transportationops.org/traffic-management-systems-and-centers/resources-traffic-management-system-and-centers/Managing-TMS-Assets-and-Resources
This web site offers access to traffic management system (TMS) resources that include:

- Key findings from TRB 2021 Workshop 1002: Managing Traffic Management Systems Assets and Resources.
- A webinar on performance measures and health indexes of ITS assets that "explores successful practices in ITS asset management such as defining goals, objectives, data sources and performance measures." The webinar also provided data management and data visualization examples, useful for monitoring the health and performance of ITS assets within the traffic management center and in the field.

Related Resource:

NOCoE Asset Management: Virtual Peer Exchange Proceeding Report, National Operations Center of Excellence Spring 2021.
https://transops.s3.amazonaws.com/uploaded_files/NOCoE_Asset%20Management%20Peer%20Exchange%20Report%202021_0.pdf
This publication describes a September 2020 virtual peer exchange that examined how transportation systems management and operations (TSMO) can be more integrated with agency asset management programs. Topics included:

- Defining transportation asset management for TSMO.
- Developing inventories for TSMO assets.
- Maintaining and operating inventories.
- Operation and maintenance of TSMO assets.

RITIS (Regional Integrated Transportation Information System), Center for Advanced Transportation Technology Laboratory, University of Maryland, 2021.
https://ritis.org/intro
From the Introduction page: RITIS is a situational awareness, data archiving, and analytics platform used by transportation officials, first responders, planners, researchers, and more. RITIS fuses data from many agencies, many systems, and even the private sector—enabling effective decision making for incident response and planning.
. . . .

RITIS tools can ingest nearly any type of data in any format. Our probe data analytics tools work with any [thi]rd party probe data provider (HERE, INRIX, or TomTom.) If an agency decides later to change their ATMS, ITS technologies, or data provider, rest assured that historic data will be preserved—providing seamless analysis between data providers and time ranges.

Related Resource:

> **RITIS Platform Features and Applications Overview**, Center for Advanced Transportation Technology Laboratory, University of Maryland, 2015.
> https://www.cattlab.umd.edu/files/RITIS%20Overview%20Book-2-2-15%20FINAL.pdf
> *From the purpose statement*: The Regional Integrated Transportation Information System (RITIS) is an automated data fusion and dissemination system that provides an enhanced overall view of the transportation network. Participating agencies are able to view transportation and related emergency management information through innovative visualizations and use it to improve their operations and emergency preparedness. RITIS also uses regional standardized data to provide information to third parties, the media, and other traveler information resources, including web sites, paging systems, and 511. There are three main RITIS components including: 1) real-time data feeds, 2) real-time situational awareness tools, and 3) archived data analysis tools.
>
> Real-Time Data Feeds: RITIS data feeds are services that provide direct access to real-time incident, event, detector, probe, weather, transit, and other data sources including ITS device status. The RITIS data feeds are designed to facilitate integration of RITIS data back into legacy and third-party systems and for third-party application developers that need access to real-time information for dynamic mobility applications. The data feeds provide for implementation flexibility both in data format and retrieval method. The RITIS platform allows each agency to determine which data elements it wishes to provide in the data feed or maintain secure and secluded from other agencies or the public.

Intelligent Transportation Systems—Benefits, Costs and Lessons Learned: 2018 Update Report, Liz Greer, Janet Fraser, Drennan Hicks, Mike Mercer and Kathy Thompson, U.S. Department of Transportation, March 2018.
https://www.itskrs.its.dot.gov/sites/default/files/executive-briefings/2018/BCLL%20Update%202018%20Combined_draft_v0.4.pdf
From the abstract:

> Intelligent transportation systems (ITS) provide a proven set of strategies for advancing transportation safety, mobility and environmental sustainability by integrating communication and information technology applications into the management and operation of the transportation system across all modes. … This report presents information on the benefits, costs and lessons learned regarding ITS planning, deployment and operations obtained from almost [20] years of evaluation data. The report is based upon three related [w]eb-based databases, known collectively as the ITS Knowledge Resources (KRs). The Knowledge Resources were developed by the U.S. DOT's ITS Joint Program Office (JPO) evaluation program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The Knowledge Resources contain over [18] years of summaries of the benefits, costs and lessons learned of specific ITS implementations, drawn primarily from written sources such as ITS evaluation studies, research syntheses, handbooks, journal articles, and conference papers. They can be accessed online at www.itskrs.its.dot.gov. The report has been developed as a collection of fact sheets presenting information on the performance of deployed ITS, as well as information on the costs and lessons learned regarding ITS deployment and operations.

> The report has been designed to be flexible for the user. This 2018 update report includes 10 new or revised fact sheets relative to the 2017 Update Report.

Chapter 4, Information Management, provides a discussion of the benefits of ITS data archiving systems (page 35 of the report, page 39 of the PDF).

NCHRP 08-36, Task 114: Transportation Asset Management for Ancillary Assets, David Rose, Keyur Shah, John Patrick O'Har and William Grenke, April 2014.
http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-36(114)_FR.pdf
From the executive summary:

> 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 [d]epartments of [t]ransportation (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 toward 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.

A section on ITS equipment discusses life cycle management and service life estimation for various devices (page 29 of the report, page 36 of the PDF).

Operations Benefit/Cost Analysis TOPS-BC User's Manual: Providing Guidance to Practitioners in the Analysis of Benefits and Costs of Management and Operations Projects, Doug Sallman, Krista Jeannotte, Rich Margiotta and Jennifer Strasser, Federal Highway Administration, June 2013.
https://ops.fhwa.dot.gov/publications/fhwahop13041/fhwahop13041.pdf
From the abstract: This document provides guidance on the setup and application of the Tool for Operations Benefit/Cost (TOPS-BC), which was developed to provide key decision support capabilities[,] including:

- The ability for users to investigate the expected range of impacts associated with previous deployments and analyses of many TSM&O [transportation systems management and operations] strategies;
- A screening mechanism to help users identify appropriate tools and methodologies for conducting a benefit/cost (B/C) analysis based on their analysis needs;
- A framework and default cost data to estimate the life cycle costs of various TSM&O strategies, including capital, replacement and continuing operations and maintenance (O&M) costs; and
- A framework and suggested impact values for conducting simple sketch planning level B/C analysis for selected TSM&O strategies.

….

The TOPS-BC tool was developed to support and complement the guidance developed as part of the FHWA Operations Benefit/Cost Desk Reference project. The Desk Reference provides more general discussion on the field of B/C analysis and methods for structuring analyses to overcome the many challenges often present when attempting to apply B/C analysis to [o]perations strategies.

NCHRP Report 713: Estimating Life Expectancies of Highway Assets, Volume 1: Guidebook, Paul D. Thompson, Kevin M. Ford, Mohammad H. R. Arman, Samuel Labi, Kumares C. Sinha and Arun M. Shirole, 2012.
Publication available at http://www.trb.org/Main/Blurbs/167189.aspx
From the foreword:

> The objectives of NCHRP Project 8-71 were to (1) develop a methodology for determining the life expectancies of major types of highway system assets for use in life cycle cost analyses that support management decision making; (2) demonstrate the methodology's use for at least three asset classes, including pavement or bridges and two others, such as culverts, signs or signals; and (3) develop a guidebook and resources for use by state DOTs and others for applying the methodology to develop highway maintenance and preservation programs and assess the effect of such programs on system performance.

Section 4.1.3, Traffic Signals, provides guidance on estimating life expectancies for these devices (page 47 of the report, page 56 of the PDF).

Related Resource:

> **NCHRP Report 713: Estimating Life Expectancies of Highway Assets, Volume 2: Final Report**, Kevin M. Ford, Mohammad H. R. Arman, Samuel Labi, Kumares C. Sinha, Paul D. Thompson, Arun M. Shirole and Zongzhi Li, 2012.
> Publication available at http://www.trb.org/Main/Blurbs/167188.aspx
> As a companion to Volume 1, this report provides additional detail and background about theories and methods for estimating asset life expectancies.

Systems Engineering Guidebook for Intelligent Transportation Systems, Michael E. Krueger, James Lewis, Carol Jacoby and Nancy Rantowich, Federal Highway Administration, California Division, November 2009.
https://www.fhwa.dot.gov/cadiv/segb/files/segbversion3.pdf
This guidebook provides direction to state and local agencies on applying systems engineering principles and practices to the development of ITS projects. ITS life cycle processes are discussed beginning on page 16 of the guidebook (page 26 of the PDF).

Research in Progress

Implementation of Life-Cycle Planning Analysis in a Transportation Asset Management Framework, National Cooperative Highway Research Program, start date: April 2019; expected completion date: November 2021.
Project description at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4545
From the objective: The objective of this research is to develop guidance coupled with one or more prototypical, analytical model(s) to support life-cycle planning and decision-making that applies life-cycle cost analysis as a component of a systemwide transportation asset management program. This guidance and associated analytical model(s) will apply quantitative asset-level, project-level, and network-level inputs to demonstrate methods for calculating life-cycle costs associated with alternative scenarios while taking into account preservation, rehabilitation, replacement, maintenance, and potential risk mitigation actions on a range of highway assets. To the degree possible, costs should reflect condition, risk and uncertainty, mobility, safety, and any other quantifiable aspect of transportation system performance. Although this research is targeted to state DOT highway assets within the overall transportation network, the research should also identify additional research necessary to expand the process to include other modes.

State Research and Resources

Arizona

Technical Memorandum #7—Implementation Plan, Intelligent Transportation Systems Strategic Plan, City of Buckeye, October 2017.
https://azmag.gov/Portals/0/Documents/MagContent/Buckeye-ITS-Strategic-Plan-Tech-Memo-7-Implementation.pdf?ver=2018-01-31-093656-550
As part of the city's ITS Strategic Plan, this technical memorandum outlines maintenance recommendations and requirements for ITS devices, including criteria for replacing or upgrading equipment. A table of estimated life cycles for specific ITS devices is provided in Table 3, ITS Device and Telecommunications Maintenance Guidelines (page 10 of the memorandum, page 12 of the PDF).

California

Replacing Intelligent Transportation System Field Elements: A Survey of State Practice, Preliminary Investigation, California Department of Transportation, January 2016.
https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/preliminary-investigations/replacing-its-field-elements-pi-a11y.pdf
This Preliminary Investigation examined agencies' approaches to replacing ITS field elements as well as related issues of planning, funding and technology service life.

See page 4 for a table summarizing the planned or expected ITS equipment replacement cycles for four states—Nebraska, North Carolina, Oregon and Washington. Two documents from Washington State DOT provide additional detail on that agency's methodologies:

- Appendix B: Washington State DOT Highway System Plan—Major Electrical Systems (Draft), 2007 (page 36 of the PDF). Table 1, Major Electrical System Inventory/Funding Needs, includes the expected life cycle for major electrical system items (see page 20 of the plan, page 55 of the PDF).
- Appendix C: Washington State DOT Major Electrical (P3) Project Prioritization Process Criteria, 2012 (page 58 of the PDF).

San Diego Region Intelligent Transportation Systems (ITS) Strategic Plan, San Diego Association of Governments, August 2011.
https://www.sandag.org/uploads/publicationid/publicationid_1730_15504.pdf
This strategic plan includes a section on ITS performance measurement (page 34 of the plan, page 42 of the PDF).

Colorado

C.9. Intelligent Transportation Systems Technical Plan, Appendix C, Technical Plans, Asset/Fund Management Guidebook, Colorado Department of Transportation, undated.
https://www.codot.gov/business/project-management/asset-and-fund-management-guidebook/technical-plans/intelligent-transportation-systems-technical-plan
From page 3 of the PDF: [Colorado DOT (CDOT)] assesses device functionality along with age, life cycle, and availability to prioritize maintenance and capital replacement activities. Device availability is defined as the time the device was inoperable or the difference between the time when the device stopped operating and the time the device was repaired. This allows CDOT to determine percent of availability at a device level, device category level, corridor, and other geographic area and statewide system level. ITS tracks its device life cycle through the

inventorying of unique device acquisition/installation date, manufacturer's expected life cycle, maintenance costs, and instances of device failure. However, although life cycle is an extremely important indicator as it pertains to ITS asset management, developing an adequate life cycle analysis can be challenging. CDOT also considers the Federal Highway Administration's (FHWA) lists of device life cycles. FHWA conducts state surveys and compiles the results to develop their own device life cycle lists. Technology gradually becomes obsolete due to changes in CDOT technology requirements. Unlike other firm assets, which are expected to be viable throughout their entire life cycle, ITS technology can quickly lack necessary coverage or interoperability needed. In this case, much of the deterioration of ITS infrastructure is evaluated on both its physical side as well as its continued viability.

C.10. Traffic Signals Technical Plan, Appendix C, Technical Plans, Asset/Fund Management Guidebook, Colorado Department of Transportation, undated.
https://www.codot.gov/business/project-management/asset-and-fund-management-guidebook/technical-plans/traffic-signals-technical-plan
From page 3 of the PDF: Traffic signals have been viewed as an aggregate unit with a useful life span of 25 years. Although the traffic signal assembly (poles and mast arms), can last 30 years or longer when properly maintained and under normal conditions. Cabinets can be expected to have a useful life span of 20 years. Controllers can be expected to have a useful life span of 15 years. However, assuming the rapid technological advances in the transportation industry, cabinets and controllers have much shorter life cycles, due to electronics, technological function obsolescence, and other factors. CDOT Signal Asset Condition Assessment Guidelines [are provided] in CDOT's Risk-Based Asset Management Plan.

Connecticut

Highway Transportation Asset Management Plan, Connecticut Department of Transportation, August 2019.
https://portal.ct.gov/-/media/DOT/documents/dplansprojectsstudies/plans/Highway-Transportation-Asset-Management-Plan-FHWA-Certified-082819.pdf
This Transportation Asset Management Plan includes details on performance measures and life cycle planning for traffic signals. Relevant sections include:

- Life Cycle Planning for Traffic Signals (page 113 of the PDF).
- CTDOT Asset Fact Sheet—Traffic Signals (page 191 of the PDF).

Florida

Statewide Intelligent Transportation Systems Performance Measures, Fiscal Year 2015/2016, Florida Department of Transportation, 2016.
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/content/traffic/its/projects_deploy/perfmeas/its-pm-annual-report-2016-final-10-19-16.pdf?sfvrsn=83321eba_0
From the introduction: As ITS evolves in Florida, developing and reporting operations performance measures is a high priority for FDOT to demonstrate and document the benefits of ITS. When FDOT's ITS [p]rogram began addressing performance in 2004, the [d]istricts did not have automated data collection systems and were initially limited to measures of basic production and usage (output). The initial output measures reported statewide were Total Annual 511 calls, Road Ranger Stops, and centerline miles of limited-access highways managed by ITS.

Widespread ITS deployment and integration will allow more accurate documented and reporting of performance measures the resulting benefits (outcome). The Florida Transportation Commission approved three ITS outcome performance measures in 2005: incident duration, travel-time reliability, and customer satisfaction. Data collection and reporting for Incident duration and customer satisfaction began in 2006.

Integrated Environment for Performance Measurements and Assessment of Intelligent Transportation Systems Operations, Florida Department of Transportation, July 2012.
https://rosap.ntl.bts.gov/view/dot/24908/dot_24908_DS1.pdf?
From the abstract: This project has developed and implemented a software environment to utilize data collected by Traffic Management Centers (TMC) in Florida, in combination with data from other sources to support various applications. The environment allows capturing and fusing the data from multiple sources. The combined data can support the performance measurements of transportation system, transportation system modeling, assessment of the benefits of Intelligent Transportation System (ITS) applications such as incident management, ramp metering, and so on, and discovery of different relationships and associations of attributes through data mining and visualization methods. The developed modules are demonstrated in a series of use cases.

Illinois

Illinois Statewide Intelligent Transportation Systems (ITS) Strategic Plan, Illinois Department of Transportation, October 2019.
https://idot.illinois.gov/Assets/uploads/files/Transportation-System/Reports/OP&P/ITS/IL%20Statewide%20ITS%20Strategic%20Plan%20-%20FINAL.pdf
From the introduction:

> The Illinois Statewide Intelligent Transportation Systems Strategic Plan provides a performance-driven direction for the deployment of ITS on a statewide basis. The plan is a mechanism for the identification and prioritization of ITS projects within a single framework to promote maximum benefits from state and federal ITS funding. This document builds upon the groundwork defined by the Statewide Concept of Operations and statewide and regional ITS architecture process, as well as numerous studies performed by ITS stakeholders in Illinois.

Section 9.1 addresses the life cycle costs of ITS projects (page 111 of the PDF).

Importance of ITS Preventive Maintenance and Transitioning to an Accelerated ITS Design Approach for Illinois Tollway, Amarpal Matharu and Michel Lavigne, Illinois Tollway, September 2018.
https://www.itsmidwest.com/2018-Annual-Meeting/presentations/ppdf/session-7/ITS%20Preventative%20Maintenance_Lavigne.pdf
This presentation discusses:

- ITS infrastructure.
- ITS preventive maintenance program.
- Cost–benefit analysis.
- Transitioning to an accelerated ITS design phase.

Iowa

Intelligent Transportation Systems (ITS) and Communications Systems Service Layer Plan, Version 1.0, Iowa Department of Transportation, January 2018.
https://iowadot.gov/TSMO/ServiceLayerPlan3.pdf
This plan provides a guide for the deployment and operations of ITS technology and the underlying network communications system. Chapter 7 presents a discussion of maintenance planning, maintenance and inventory management tools, preventive maintenance, response maintenance and scheduled device replacement. *From page 100 of the plan (page 110 of the PDF)*:

> As a general guideline for planning and budgeting purposes, the typical useful life for DMS components is 15-20 years, and 7-10 years for most other ITS and communications systems. This replacement is particularly important with network infrastructure due to the rate at which cybersecurity threats and corresponding protections are evolving.

The plan concludes with recommendations regarding performance management (page 107 of the plan, page 117 of the PDF).

Michigan

Implementation Recommendations for Management Procedures for Data Collected Via CAV, Zahra Bahrani Fard, Adela Spulber and Brian Reed, Michigan Department of Transportation, April 2018.
https://www.michigan.gov/documents/mdot/A3_Implementation_Recommendations_for_Management_Procedures_5-25-2018_624431_7.pdf
From the executive summary: The Michigan Department of Transportation (MDOT) is a leader amongst state transportation departments in the testing and deployment of intelligent transportation systems (ITS) and connected and automated vehicle (CAV) applications. As part of these efforts, MDOT asked a team led by the Center for Automotive Research (CAR) and assisted by WSP to evaluate the collection, management, and use of CAV data and to make recommendations to develop integrated, dynamic, and adaptive data management systems. This report builds on previous reports from 2013 and 2015 titled Management Procedures for Data Collected via Intelligent Transportation Systems. This research focuses on conveying the current state of ITS and CAV data systems and their connections. The goal of this report is to help MDOT increase the overall coherence of the [d]epartment’s data systems, pursue data systems integration, and eliminate duplicative efforts. The report also aims to identify critical needs, best practices and strategies for better data management practices. The intended audience includes MDOT staff, program managers, and contractors responsible for data systems, as well as users of MDOT data systems from the [d]epartment of outside organizations.

“Management Procedures for Data Collected Via Intelligent Transportation Systems,” Qiang Hong, Richard Wallace, Eric Paul Dennis, Brian Reed, William Tansil and Matt Smith, *Journal of Civil Engineering and Architecture,* Vol. 9, Issue 9, September 2015.
Citation at
https://www.researchgate.net/publication/283835143_Management_Procedures_for_Data_Collected_via_Intelligent_Transportation_Systems
From the abstract: The benefits of being proactive in Intelligent Transportation Systems (ITS) adoption are numerous. ITS can facilitate a safe and efficient transportation system, improve public safety, assist research programs, stimulate economic growth, and improve the environment. However, a disadvantage in being at the forefront of technological advances is

that technologies may be deployed before they are fully mature. In the case of Michigan, several ITS programs have been launched successfully, but independently of each other. To effectively capitalize and leverage existing and future opportunities, the State of Michigan should develop a statewide master/strategic plan for database aggregation across ITS, geographic information systems (GIS), and transportation asset management subsystems and programs. The plan should be developed in conjunction with key stakeholders including Michigan Department of Transportation (MDOT), the Michigan Department of Technology, Management & Budget (DTMB), and other key stakeholders.

Minnesota

Transportation Asset Management Plan, Minnesota Department of Transportation, June 2019.
https://www.dot.state.mn.us/assetmanagement/pdf/tamp/tamp.pdf
From the purpose:

> In addition to being a federal requirement, the [Transportation Asset Management Plan] is a planning tool to help MnDOT further evaluate risks, develop mitigation strategies, analyze life cycle costs, establish asset condition performance measures and targets, and develop investment strategies.

The plan includes information on ITS inventory and replacement value and on ITS data collection, management and reporting practices (see page 75 of the report, page 81 of the PDF).

New Jersey

"Manual of Guidelines for Inspection and Maintenance of Intelligent Transportation Systems," Kaan Ozbay, Eren Erman Ozguven, Tolga Sertel, Tim Bourne, Nazhat Aboobaker, Bruce Littleton and V. Kivanc Caglar, *Transportation Research Record 2129,* December 2009. Citation at https://journals.sagepub.com/doi/abs/10.3141/2129-11
From the abstract: Proper installation, care and maintenance of Intelligent Transportation Systems (ITS) equipment increase the efficiency and connectivity of the surface transportation systems, conserve [the] public's investment in the highway system, and ensure that the system will continue to provide maximum benefits to travelers. Consequences of ITS equipment failures and malfunctions caused by the lack of technical knowledge, inadequate inspection during installation and improper maintenance practices can be "increased motorist and maintenance costs" (unnecessary failures or malfunctions, increasing personnel and repair time, replacement part costs, and spare part inventory requirements), "increased number of accidents" and "increased delays, degraded air quality and fuel consumption." Prior to this study, NJDOT [New Jersey DOT] did not have an inspection and maintenance manual as a reference document to assist NJDOT's inspectors, ITS design, traffic operations and maintenance personnel to minimize the aforementioned problems, to monitor the performance and failure rates, and to provide a cost-effective approach to inspecting, maintaining, upgrading, and operating the ITS equipment on roadways. Rutgers University, in close collaboration with Orth-Rodgers and Associates, Inc., developed a state-of-the-art and practical ITS inspection and maintenance manual, and implemented this manual in the form of a user friendly software tool. This tool provides NJDOT with complete, practical and efficient inspection procedures for the proper installation and preventive or routine maintenance of ITS equipment. The initial feedback after several hands-on training workshops from the first group of expert users of the manual and its software [was] found to be very positive and encouraging.

Pennsylvania

Intelligent Transportation Systems Maintenance Standards, Pennsylvania Department of Transportation, 2011.
https://www.dot.state.pa.us/public/pubsforms/Publications/PUB%20697.pdf
From the introduction: The purpose of this publication is to provide guidance to those responsible for the maintenance of Intelligent Transportation Systems (ITS) devices throughout the Commonwealth. With the continued deployment of ITS devices, maintenance is an increasing issue. In order to provide ITS practitioners a consistent framework for maintaining ITS devices and systems, ITS maintenance standards must be developed and utilized. This document will detail specific baseline maintenance activities for ITS devices and systems.

Texas

Warrants and Criteria for Installing and Sunsetting TxDOT ITS Equipment, Kevin Balke, Nadeem Chaudhary, Bob Brydia, Praprut Songchitruksa and Geza Pesti, Texas Department of Transportation, January 2014.
https://static.tti.tamu.edu/tti.tamu.edu/documents/0-6773-1.pdf
From the abstract: Over the past several decades, the Texas Department of Transportation (TxDOT) has made a significant investment in deploying and developing intelligent transportation systems (ITS) devices, such as closed circuit television (CCTV), traffic sensors and dynamic message signs (DMS), to assist in managing traffic operations. However, as these systems have matured and as financial resources have become more constrained, TxDOT needs to become more strategic in their decision-making as to when and where to deploy new ITS devices and systems and when and where to continue supporting and/or upgrading systems that have met their life expectancy. The goal of this project was to develop guidelines, criteria and procedures to assist TxDOT in their decision-making specific to installing, repairing and/or removing ITS field devices and systems. Specifically, through this project the research team assisted TxDOT by: 1) developing warrant conditions and criteria for assessing when and where to install new ITS devices and systems, 2) providing sunset requirements and criteria for determining when to no longer support deployed ITS devices and systems, and 3) developing an analytical framework for identifying and prioritizing mission critical devices and systems for upgrade and maintenance.

Virginia

"Decision Support System for Planning Traffic Operations Assets," Milos N. Mladenovic, Katerina Mangaroska and Montasir M. Abbas, *Journal of Infrastructure Systems*, Vol. 23, Issue 3, 2017.
Citation at https://trid.trb.org/view/1455258
From the abstract: Intelligent transportation systems (ITS) assets provide the opportunity to improve the efficacy of the current transportation infrastructure. However, transportation agencies face continuous challenges in planning and managing ITS assets. The focus of this research is on improving the planning of traffic-signal control technology as an important ITS subsystem. To this end, this research presents a decision support system (DSS) for evaluation of controller software assets. The proposed DSS consists of four components, namely knowledge, model, dialog, and database management. The core of the DSS is a fuzzy analytic hierarchy process methodology, relying on expert-knowledge acquisition. The proposed DSS is implemented on a case study for the Virginia Department of Transportation. The results indicate that the experts and the integrated DSS play a major role in obtaining a precise and consistent evaluation of signal controller software alternatives. Moreover, the developed decision support

methodology is transferable among agencies. Finally, the proposed DSS provides a framework for further development of evaluation methods for other ITS assets.

Washington

ITS Strategic Plan 2010-2020, Seattle Department of Transportation, March 2010.
https://www.seattle.gov/Documents/Departments/SDOT/TechnologyProgram/ITSStrategicPlan20102020.pdf
This strategic plan outlines a 10-year approach to implementing ITS infrastructure in Seattle. ITS performance measures are discussed on page 47 of the plan (page 51 of the PDF).

Wisconsin

WisTransPortal System, Wisconsin Traffic Operations and Safety Laboratory, 2019.
https://transportal.cee.wisc.edu/about/
From the web page: The *WisTransPortal Data Hub* has been developed through ongoing collaboration between the Wisconsin Traffic Operations and Safety (TOPS) Laboratory at the University of Wisconsin–Madison and the Wisconsin Department of Transportation (WisDOT) Bureau of Traffic Operations (BTO) to support emerging requirements for transportation operations, planning, and research. The system provides a central source of traffic operations, safety, and intelligent transportation systems (ITS) data for Wisconsin highways, with specific capabilities for data archiving, real-time services, and server applications development. In recent years, the WisTransPortal has been expanded to support research and analysis capabilities along the local road network as well, particularly in the area of traffic safety.

The WisTransPortal ITS project architecture, part of the larger Wisconsin Statewide ITS Architecture, provides a complete description of existing and planned elements, interfaces, and operational requirements of the system. Connections between the WisTransPortal and other major ITS systems such as the Wisconsin 511 traveler information system and the WisDOT Traffic Management Center (TMC) Advanced Traffic Management System (ATMS) are also represented. The WisTransPortal has been operational since 2003 and is used throughout Wisconsin and regionally by state and local governments, law enforcement, universities, engineering firms, and others.

International Research and Resources

Australia

"Reliability Centred Maintenance (RCM) for Intelligent Transport Systems (ITS)," Q. Wazirzada, 27th *Australian Road Research Board Conference*, 2016.
Citation at https://trid.trb.org/view/1446690
From the abstract: Reliability Centred Maintenance (RCM) aims to adopt a flexible and systematic approach that focuses on preventing the consequences of failure rather than the failures. In other words, it analyses how, why and when the systems in question fail. Some failures have a much greater impact and may have a lower probability as compared to others with a milder impact but a much higher probability. RCM methodology directs attention to predicting and proactively preventing high consequence failures that take longer to fix[,] i.e.[,] failures that reduce system reliability and availability. The application of fundamental engineering concepts such as engineering risk analysis provides the maintenance practitioner a foundation for identifying potential failures and assigning criticality or priority for fixing them. RCM uses operations and maintenance data to analyse failure modes and to assign criticality.

This criticality is utilised to assign maintenance resources more efficiently. This helps the maintenance practitioners to maximize operational performance of Intelligent Transport Systems (ITS) assets in the network, manage within limited maintenance budgets and manage asset life cycle in an efficient manner. This paper highlights the benefit of an RCM framework for ITS and the application of some RCM techniques well-suited to ITS.

Reliability-Centred Maintenance Strategy and Framework for Management of Intelligent Transport System Assets, I. Espada and L. Inglis, Austroads, 2016.
Citation at https://trid.trb.org/view/1446724
From the abstract: This report provides a reliability-centred maintenance (RCM) strategy and framework to manage intelligent transport system (ITS) assets. ITS assets play a key role optimising efficiency and minimising crash risk in modern road network operations. ITS devices, however, fail frequently and every time they fail, the device can either be unavailable or operating in a degraded state for a long time. Unscheduled maintenance is costly and faults can potentially occur during critical times when the ITS asset is required to be functioning as designed/intended causing avoidable congestion cost and an increase in the risk of an incident. RCM is the application of engineering principles to manage the consequences of failure under a constrained maintenance budget. The use of RCM was raised in Austroads project AT1534 in 2013 as a potential approach to dealing with the issue of ITS failures under constrained maintenance budgets. The report covers the identification of key success factors, confirmation of the benefits and acceptability of RCM within jurisdictions including their contractors and suppliers, design of an RCM process template, and drafting of a road map for moving from the current practice to RCM.

Part 7: Intelligent Transport Systems Maintenance, Traffic and Road Use Management, Volume 4: Intelligent Transport Systems and Electrical Technology, Department of Transport and Main Roads, State of Queensland, November 2015.
https://www.tmr.qld.gov.au/-/media/busind/techstdpubs/Traffic-management/Traffic-and-Road-Use-Management-manual-TRUM/Volume-4/Volume4Part7.pdf?la=en
From the scope: This document contains the minimum requirements for maintenance practices applicable to Intelligent Transport Systems (ITS) equipment that will allow these installations to continue operating safely, reliably, efficiently and effectively for the duration of their economic service life. The Intelligent Transport Systems maintenance regime includes electrical, operational, structural and environmental aspects, covering both scheduled and unscheduled work.

European Union

Key Performance Indicators for Intelligent Transportation Systems—Final Report, European Commission, February 2015.
https://ec.europa.eu/transport/sites/transport/files/themes/its/studies/doc/its-kpi-final_report_v7_4.pdf
From the introduction: Directorate General for Mobility and Transport (DG MOVE) of the European Commission engaged AECOM to carry out a Study on Key Performance Indicators (KPIs) for Intelligent Transport Systems (ITS). This Final Report outlines the process that AECOM has utilised to establish current levels of KPI use, consult with industry experts and establish a set of recommended KPIs for implementation within and across the EU. The objectives of the study as a whole were:

- To undertake a state of the art review of KPIs relating to Intelligent Transport Systems, with particular focus on the type, method of calculation, terminology used and approaches and how these vary between [m]ember [s]tates; and
- To define/recommend a set of common KPIs for road transport, with supporting guidance on their application, presentation and reporting.

Related Resource

"A Life-Cycle Cost-Analysis Approach for Emerging Intelligent Transportation Systems With Connected and Autonomous Vehicles," Jingqin Gao, Kaan Ozbay, Fan Zuo and Abdullah Kurkcu, *Transportation Research Board 97th Annual Meeting*, Paper #18-03895, January 2018.
Publication available at
https://www.researchgate.net/publication/325370388_A_Life_Cycle_Cost_Analysis_Approach_for_Emerging_Intelligent_Transportation_Systems_with_Connected_and_Autonomous_Vehicles
From the abstract: The objective of this paper is to describe five fundamental differences of [l]ife [c]ycle [c]ost [a]nalysis (LCCA) between a conventional transportation system and a technology-oriented Intelligent Transportation System (ITS). These five differences are related to the temporal behavior inflation, consideration of uncertainty, out-of-pocket costs, risks in terms technical obsolescence, and inventory management. A novel conceptual ITS LCCA framework which is introduced to capture these differences has the potential to be more effective in a connected and autonomous vehicle (CAV) environment. The findings from an in-depth discussion in the inflation rate indicate that the trend of the inflation rate for ITS components does not need to follow the general trend of consumer and producer price index. In addition, a viable alternative to quantify user cost is introduced by utilizing outputs from traffic simulations combined with traffic delay, vehicle operation, and crash risk cost models. Hypothetical failure rate scenarios were developed through the use of an open-source micro-simulation software namely, SUMO, in a connected vehicle environment. This approach is shown to be useful in quantifying user costs. Moreover, it can be readily implemented within the ITS LCCA framework when actual failure rate information becomes available.

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Appendix A: Survey Questions

The following survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Transportation System Operations.

Survey on Life Cycle Planning for Intelligent Transportation System Assets

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Note: The response to the question below determined how a respondent was directed through the survey.

(Required) Does your agency gather data to conduct life cycle planning for intelligent transportation system (ITS) assets? For Caltrans, these assets include the items listed below. Typically, life cycle planning includes an examination of each asset's preservation, maintenance, repair, replacement and obsolescence.

- Changeable message signs.
- Closed circuit televisions.
- Extinguishable message signs (displays a fixed message).
- Highway advisory radios.
- Ramp metering systems.
- Roadway weather information systems.
- Traffic census stations.
- Traffic monitoring detection stations.
- Traffic signals.

Response Options:

- No. (Directed the respondent to the **Agencies Not Conducting Life Cycle Planning for ITS Assets** section of the survey.)
- Yes. (Directed the respondent to the Changeable Message Signs question set of the **Agencies Conducting Life Cycle Planning for ITS Assets** section of the survey.)

Agencies Not Conducting Life Cycle Planning for ITS Assets

Is your agency considering adopting a model or methodologies to assess the condition and monitor the life span of ITS assets?

- No.
- Yes. (Please briefly describe your agency's plans.)

Note: After responding to the question above, the respondent was directed to the **Wrap-Up** section of the survey.

Agencies Conducting Life Cycle Planning for ITS Assets

Note: The next sections of the survey asked respondents to describe how their agencies assess the life cycle of each of the nine ITS asset types. After being given the opportunity to answer questions related to all nine ITS asset types, respondents were directed to the **Other Life Cycle Planning Practices** question set and the remaining portions of the survey.

<u>Changeable Message Signs</u>

(Required) Does your agency gather data to conduct life cycle planning for **changeable message signs**?

- Yes
- No (Directed the respondent to the question set for **Closed Circuit Televisions**.)

Asset Condition

1. Are there multiple components included in a representative example of this ITS asset?
   - No
   - Yes (Please describe each component and respond to Questions 1A and 1B.)

1A. Does your agency track the life span of each component part?
   - No
   - Yes

1B. Which part of the ITS asset determines its overall condition?

2. What methodologies or techniques are used to assess ITS asset condition? Select all that apply.
   - Inspection reports
   - Age-based assessment
   - Engineering judgment
   - Other (Please describe.)
3. Does your agency apply standard categories in its condition reports?
   - No
   - Yes (Please describe the standard categories applied in condition reports.)
4. What is your agency's inspection interval for this asset type?
   - None
   - Real time
   - Daily
   - Weekly
   - Monthly
   - Quarterly
   - Three times a year
   - Twice a year
   - Once a year
   - Every two years
   - Other (Please describe.)
5. What is your agency's frequency for preventive maintenance?
   - None
   - Monthly
   - Quarterly
   - Twice a year
   - Once a year
   - Every two years
   - Other (Please describe.)
6. How do maintenance activities affect the remaining service life of an individual device?
7. At what point in the asset's life, or under what circumstances, does your agency attempt to improve the asset's condition?

Estimated Service Life

1. What is the estimated service life of this ITS asset type (in years)?
2. Does industry obsolescence influence the asset's estimated service life?
   - No
   - Yes (Please describe how service life is impacted.)

3. What factors affect the remaining life of this asset type? Select all that apply.
   - Age
   - Condition
   - Engineering judgment
   - Installation date
   - Manufacturer support of device
   - Manufacturer warranty
   - Mean time before failure
   - Milestones in the advancements in technology
   - Physical environment (environmental conditions)
   - Physical location
   - Usage.
   - Other (Please describe.)
4. When does your agency replace this asset type? Select all that apply.
   - At the end of its useful life
   - In connection with roadway replacement or new construction project
   - When it fails to meet performance standards (for example, uptime or accuracy)
   - When it has become obsolete
   - When it no longer functions as originally intended
   - When one or more components fail
   - When replacement parts are no longer available
   - Other (Please describe.)
5. Please describe any calculations your agency uses to determine remaining service life.

Note: In the online survey, the question blocks presented above for the **Changeable Message Signs** section were repeated for each of the remaining ITS asset types. After being given the opportunity to answer the **Traffic Signals** questions set, respondents were directed to the **Other Life Cycle Planning Practices** section.

Other Life Cycle Planning Practices

1. Does your agency include devices other than those included in this survey in its inventory of ITS assets?
   - No
   - Yes (Please identify these other ITS devices.)
2. Does your agency classify or categorize ITS assets in terms of their significance to agency operations?
   - No
   - Yes (Please describe this classification or categorization.)
3. Does your agency maintain a central repository of ITS asset data?
   - No
   - Yes (Please describe this repository.)
4. How does the ITS data repository relate to your agency's overall transportation asset management system (TAMS)?
   - We don't have an ITS data repository.
   - The ITS data repository is separate from and does not interface with our TAMS.
   - The ITS data repository is separate from but does interface with our TAMS.
   - The ITS data repository is part of our TAMS.
   - Other (Please describe.)

5. Does your agency use performance measures to track ITS assets?
    - No
    - Yes (Please provide examples of these performance measures.)

Assessment and Recommendations

1. What successes has your agency experienced when developing life cycle planning practices for ITS assets?
2. What challenges has your agency encountered when conducting life cycle planning for ITS assets?
3. What are your top three recommendations for other agencies seeking to improve life cycle planning practices for ITS assets?
    - Recommendation 1:
    - Recommendation 2:
    - Recommendation 3:
4. If available, please provide links to documentation that describes your agency's policies and practices for life cycle planning for ITS assets. Send any files not available online to carol.rolland@ctcandassociates.com.

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.