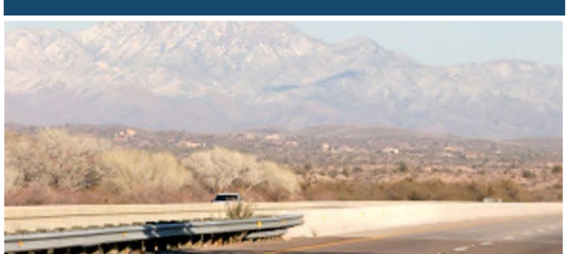
PERFORMANCE MEASURES AND HEALTH INDEX OF INTELLIGENT TRANSPORTATION SYSTEMS ASSETS



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16. Abstract
Asset management for intelligent transportation systems (ITS) is still a relatively new concept. ITS have played an important role in improving the safety, efficiency, and overall performance of the transportation system. ITS asset management helps transportation agencies better manage, operate, maintain, and expand their ITS while maintaining performance at desired levels. ITS is the application of a wide range of technologies to transportation for the purpose of improving safety and mobility.

The objective of this task order is to synthesize and identify best practices in ITS asset management. This includes utilizing data from ITS assets to provide visualization and summary of that data to support ITS asset management, as well as to advance transportation systems management and operations (TSMO) capabilities and support integration of TSMO into the management and operations of the transportation management centers (TMCs) and agency's transportation system. This project will further investigate ITS asset management practices, including optional State or local agency programmatic-level performance measures that best support the TSMO Implementation Plan; align with the States' departments of transportation's (DOT's) Transportation Asset Management Plan, maintenance management system, and Long-Range Transportation Plan; and meet the needs of the TMC and State's transportation system.

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FACTORS APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
In.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
$in.^2$	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1,000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/$in.^2$	poundforce per square inch	6.89	kilopascals	kPa

***SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)**

SI* (MODERN METRIC) CONVERSION (continued)

APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
mm	millimeters	0.039	inches	in.
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in.^{2}
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

***SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)**

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ATMS	advanced traffic management system
Caltrans	California Department of Transportation
CCTV	closed-circuit television
CFR	Code of Federal Regulations
DMS	dynamic message sign
DOT	department of transportation
FHWA	Federal Highway Administration
GIS	geographic information system
IT	information technology
ITS	intelligent transportation systems
LCP	life-cycle planning
NHS	National Highway System
NITTEC	Niagara International Transportation Technology Coalition
NMS	network management system
NYSDOT	New York State Department of Transportation
QA	quality assurance
QC	quality control
TAM	transportation asset management
TAMP	Transportation Asset Management Plan required under 23 U.S.C. 119(e)
TMC	transportation management center
TMS	transportation management system
TSMO	transportation systems management and operations
USDOT	U.S. Department of Transportation

EXECUTIVE SUMMARY

State and local departments of transportation (DOTs) have benefitted greatly from using intelligent transportation systems (ITS) to improve the safety, efficiency, and performance of transportation networks. Devices such as closed-circuit television (CCTV) cameras monitor traffic flows on roadways and assist with incident management efforts, while devices such as ramp meters help improve the flow of traffic on the nation's roadways. The practice of inventorying all these ITS devices and recording critical information, such as device location, installation date, age, and condition, with the purpose of monitoring their condition for periodic maintenance and eventual replacement is referred to as transportation asset management (TAM) of ITS devices.

TAM for traditional roadway infrastructure has been in place for many years. This includes monitoring the condition of pavement, bridges, and other roadway infrastructure such as tunnels. Many States across the nation are realizing the importance of tracking the health of these ITS devices, and general practices include inventorying the ITS devices and establishing voluntary State performance measures to monitor their ITS networks. This allows for more efficient planning and budgeting for replacement of these ITS devices once their recommended life-cycle has passed.

Most State DOTs and local agencies have already taken steps towards inventorying and actively managing their ITS devices. Their individual progress covers a broad spectrum from States that have centralized ITS asset repositories and developed obsolescence plans, to other States that are now starting to articulate goals and objectives of their ITS asset management efforts. States today are tracking the performance of their ITS devices with voluntary performance measures such as percentage uptimes and device reliability. Some States have more sophisticated asset management inventory systems and processes that tie device inspections to applications that generate work orders. This can be considered a good practice for adoption by other States. Potential actions discussed in this report include voluntarily establishing State goals, objectives, and performance measures as the foundation of an ITS Asset Management Plan. Additional actions include creating a centralized ITS device repository and developing a replacement plan that addresses estimated cost and timelines for replacing aging devices.

In this report, TAMP refers to the federally-required asset management plans prepared by State DOTs (23 USC 119(e) and 23 CFR Part 515), while asset management plans or ITS Asset Management Plan refer to voluntary plans created by States and local agencies. This report introduces the concept of TAM in general and for the specific case of ITS devices. The report also addresses the importance and uses of the data and performance measures when applying TAM to ITS devices. Information is also provided on TAM performance measures, health index, and reporting and visualizing for ITS devices. Several case studies of locations that have implemented successful asset management techniques, such as Georgia, Utah, and Nevada, are also provided.

CHAPTER 1. INTRODUCTION

Traditional TAM, which inventories the traditional roadway and bridge assets, has been adopted and implemented by States for several years now. Through extensive collection and analysis of data, these plans can help State and local agencies operate, maintain, upgrade, and expand physical assets throughout their life-cycle.

The TAMPs of all 50 States, the District of Columbia, and Puerto Rico are listed on the Federal Highway Administration (FHWA) website https://www.fhwa.dot.gov/asset/plans.cfm.[14]

While State DOTs have developed their TAMPs to address NHS pavement and bridge assets, few have added or included ITS devices into their TAMPs. A handful of States, such as California, Utah, Minnesota, and Nevada, have added their ITS devices as part of the larger TAMP.

As a data-driven process, TAM uses data collected through transportation management centers (TMCs), field inspections, and manufacturer-provided recommendations to help State DOTs and local agencies manage their assets. Many of these ITS assets play a very important role in the safety of the traveling public and in improving the performance of the roadway network. States and local agencies benefit by knowing about the asset's current and historical performance. The agencies' risk is also diminished through avoidance of unreliable technology.

DOCUMENT PURPOSE

This document provides agencies information related to asset management practice by providing principles for ITS asset management. ITS devices "apply information, communication, and sensor technologies to vehicles and transportation infrastructure to provide real-time information for road users and transportation system operators to make better decisions."[41] This includes devices such as closed-circuit television (CCTV) cameras, dynamic message signs (DMSs), vehicle detection sensors, road weather information systems, and highway advisory radio stations. This document addresses how to identify goals and objectives, how to identify data sources, and how to best use the data for ITS asset management activities. It discusses how to develop data needs and voluntary State or local performance measures to meet the goals and objectives; how to develop a plan for reporting, visualizing, and managing ITS asset and performance data; and how to integrate this information with transportation systems management and operations (TSMO) plans and asset management plans for better analysis. This document includes a section of implemented practices as well as several State DOT case studies.

OBJECTIVES

This section discusses the project objectives identified as part of this task.

Best Examples of Intelligent Transportation Systems Management by Departments of Transportation and Agencies

During the literature search and research on the topic, several States demonstrated an advanced understanding of the importance of ITS asset inventory and development of voluntary State performance measures to track how their devices were performing. States such as Georgia and Florida have taken steps to inventory devices and pertinent information about the devices to monitor their performance, track life-cycles, and plan subsequent replacement of the devices once they have reached their useful life span. Some States, such as Minnesota, Nevada, and California, have included ITS devices as part of their overall State DOT TAMP, while other State DOTs have not yet included them.

The California Department of Transportation (Caltrans), as part of its TAMP development, selected four primary asset classes—pavement, bridges, drainage, and TMS. Several examples of the TMS include CCTV cameras, ramp meters, variable message signs, vehicle detectors, traffic signals, and highway advisory radios. The Minnesota DOT TAMP includes ITS and signal systems in addition to pavement and bridge assets.

Current State of Performance Measures for Intelligent Transportation Systems Devices

Some of the more advanced States have developed a set of voluntary State performance measures to track device and systems performance. Several of the States interviewed that are just beginning do not have performance measures identified. Some of the States have adopted performance measures to include device uptime, device reliability, and data accuracy.

Need for Intelligent Transportation Systems Asset Management Plans

Throughout this report, one of the goals is to increase the awareness of State DOTs about the importance of having an ITS Asset Management Plan that addresses the process of inventorying and monitoring the health of the ITS devices in an effort to more efficiently manage the assets. Tracking critical information about the devices, such as installation date, and having access to the device performance and maintenance records, helps with resource allocation, provides agencies the foundation to make more informed decisions about device reliability, and helps agencies anticipate and plan for device replacement.

Developing a Comprehensive Intelligent Transportation Systems Asset Management Plan

This report provides State and local DOTs with information needed to develop a comprehensive ITS Asset Management Plan. Chapter 3 provides information from setting goals, objectives, and voluntary performance measures to processes and strategies to implement. Many examples of visualization tools used by several States have also been included to help States put together or improve their ITS Asset Management Plans and programs. The ITS Asset Management Plan can be a stand-alone plan or part of a State DOT TAMP.

TARGET AUDIENCE

The target audience for this report includes any State, county, and/or local DOT agencies that own and deploy ITS devices and systems. Personnel working in TMCs who work daily with these ITS devices and are familiar with the data produced by the devices can benefit from this report. Other policy and decision makers, agency procurement departments, ITS equipment vendors, and system integrators are additional professionals who could benefit from the content and examples provided in this document.

DOCUMENT ORGANIZATION

The document is organized in a series of chapters that include an introduction to ITS asset management (chapter 1) and background information obtained through a literature search (chapter 2). Chapter 3 provides information related to the performance management and health index of ITS assets, while chapter 4 discusses how to develop a plan for performance data management. Chapter 5 addresses ITS asset management and operations. Implemented practices are provided in chapter 6, and case studies providing valuable information to help States initiate these efforts or improve on current endeavors are included in chapter 7. Appendix A provides several examples of performance measure reports and dashboards developed by State and local agencies. Appendix B includes references for the content provided.

CHAPTER 2. BACKGROUND AND LITERATURE SUMMARY

The chapter discusses how key information for this literature summary was gathered and lists all the agencies that were contacted. It briefly mentions the processes several of the States have put in place and describes voluntary performance measures and data currently gathered as well as methods of visualizing the data.

As part of the literature search, 27 State DOTs, local DOTs, and other agencies were contacted or their information was reviewed online on their websites. These State DOTs include members of the Federal Highway Administration (FHWA) Transportation Management Center Pooled Fund Study Group and additional State DOTs not members of the TMC Pooled Fund Study Group. Phone interviews were conducted with several State DOTs, including Nevada DOT and Georgia DOT. Table 1 lists the agencies that provided information about their intelligent transportation systems (ITS) asset management efforts.

Table 1. Agencies and transportation management centers contacted as part of the literature review.

Alabama Department of Transportation (DOT)	Ministry of Transportation of Ontario	North Dakota DOT
Arizona DOT	Nebraska DOT	Ohio DOT
California DOT	Nevada DOT	Pennsylvania DOT
Colorado DOT	New Hampshire DOT	Rhode Island DOT
District of Columbia DOT	New Jersey DOT	South Carolina DOT
Florida DOT	New York State DOT	South Dakota DOT
Georgia DOT	New York City DOT	Texas DOT
Louisiana DOT	Niagara International Transportation Technology Coalition (NITTEC)	Utah DOT
Minnesota DOT	North Carolina DOT	Wisconsin DOT

Source: Federal Highway Administration.

Performance Measures and Processes

The establishment of performance measures is a key part of the development of a structured asset management program. Agencies demonstrate what is important to them and their programs depending on the measures they choose to track and improve on.

Some of the voluntary ITS performance measures identified by several State DOTs interviewed include device uptime (usually 90 percent device uptime), maintenance response times, and device mean time between failures. Several of the State DOTs also mentioned data accuracy as a performance measure.

The agencies discussed several of the processes they were undertaking as part of their asset management practices. All of the agencies interviewed had an inventory of ITS devices, regardless of whether these tools were Excel spreadsheets or more complex databases. The more sophisticated of these databases also include maintenance-ticketing systems that issue work orders for devices that need repairs. For example, New York State Department of Transportation (NYSDOT), Minnesota DOT, and Niagara International Transportation Technology Coalition (NITTEC) were three agencies utilizing these maintenance-ticketing systems. Utah DOT, Florida DOT, and South Carolina DOT also have fiber optic plans to track the location and general attributes of their fiber, such as the side of the road the fiber is installed on and the depth of the fiber run.

Several of the agencies interviewed, including Wisconsin DOT, indicated the use of network management systems (NMS) to track the general functioning of the network and to provide alerts when the network is experiencing an interruption in services. Several of the agencies indicated having ITS maintenance contracts to ensure the devices were monitored and functioning as intended.

Dashboards were also a common tool mentioned by several of the agencies to help with visualization of the information. Some of the tools used in visualization included Tableau and Excel. Several sample reports and dashboards are included in appendix A.

In general, all of the agencies interviewed recognize the importance of inventorying their ITS devices and monitoring the health of the devices. Several of the State DOTs have more years of experience in this area and, thus, have more mature practices. A small number of State DOTs are just beginning to set up their ITS asset management programs.

CHAPTER 3. PERFORMANCE MANAGEMENT AND HEALTH INDEX OF INTELLIGENT TRANSPORTATION SYSTEMS ASSETS

This chapter outlines, describes, and expands upon additional information for the performance management and health index of intelligent transportation systems (ITS) assets. Use of these practices is not required under Federal law. The specific information included here is as follows:

- Identification of the goals and objectives of performing ITS asset management and performance measurement.
- Details on the ITS asset performance measures and data requirements.
- Descriptions of the ITS performance measurement parameters and the sources to obtain the performance measurement data.
- Data requirements and framework, including information on the ITS asset inventory data points, data collection frequency, and temporal and special resolutions.
- Descriptions of the process and strategies that are involved with ITS asset management and performance measurement.
- Methods to coordinate asset management with other departments and agencies.

IDENTIFY INTELLIGENT TRANSPORTATION SYSTEMS ASSET MANAGEMENT GOALS AND OBJECTIVES

Asset management describes a systematic approach to managing assets by maintaining, upgrading, and operating physical assets cost effectively. Asset management uses economics and engineering principles to develop cost-effective management, programming, and resource allocation decision tools. This includes a preservation plan based on life-cycle cost analysis. Generally, asset management plans include goals and objectives and outline how people, processes, and tools interact to address the goals and objectives.

Many State DOTs have developed TAMPs that include ITS devices as part of their planning. Table 2 is a listing of the asset management plans, predominantly TAMPs, that were reviewed during the literature search. This table shows which ITS properties are listed in the asset management plan and if there is discussion of:

- ITS asset condition.
- Voluntary ITS performance targets.
- ITS Life-cycle planning.
- ITS Risk analysis.
- ITS Financial Plan.

Table 2 denotes if ITS "field devices" were discussed within the asset management document Asset Management Practices for ITS Infrastructure (2019).[38] The devices refer to ITS field infrastructure such as closed-circuit television (CCTV) cameras, dynamic message signs (DMSs), vehicle detection sensors, road weather information systems, highway advisory radio stations, etc.

Table 2. Intelligent transportation systems assets in State-level asset management plans.

State – Plan (Year)	FHWA Submittal	ITS Asset Classes Included	Condition	Performance Targets	Life-Cycle Costs	Risk Analysis	Funding
Alaska – Asset Management Synthesis for the Parks Highway Corridor (2012)	N	■ Field devices.	Y	N	N	N	N
California TAMP (2017/2018)	Y	■ Field devices.	Y	N	N	N	N
Colorado Risk- Based Asset Management Plan (2019)	Y	■ Field devices. ■ Communications.	Y	Y	Y	Y	Y
Connecticut TAMP (2019)	Y	■ Field devices.	Y	Y	N	N	N
Georgia TAMP (2019)	Y	■ Field devices. ■ Communications and networking. ■ Hardware.	N	N	N	N	N
Minnesota TAMP (2019)	Y	■ Field devices. ■ Communications. ■ Hardware and software.	Y	Y	Y	Y	Y
New Jersey TAMP (2019)	Y	■ Field devices. ■ Software.	Y	Y	Y	Y	Y
Pennsylvania TAMP (2019)	Y	■ Field devices.	N	N	N	N	N
Rhode Island TAMP (2019)	Y	■ Field devices. ■ Communications and networking. ■ Hardware and software.	Y	Y	Y	Y	Y
Utah TAMP (2019)	Y	■ Field devices. ■ Communications.	Y	Y	Y	Y	Y
Nevada TAMP (2019)	Y	■ Field devices.	Y	Y	Y	Y	Y

Source: North/West Passage Pooled Fund.

FHWA = Federal Highway Administration, ITS = Intelligent transportation system, TAMP = Transportation Asset Management Plan.

Identify Goals and Objectives

Understanding the basic definition that a goal is an abstract, higher-level target or long-term purpose and that an objective is an achievement or stepping stone to help meet the higher-level goal, many agencies have identified the goals and objectives of their ITS asset management program. In certain cases, the identified overall goals are really their overarching agency goals. Table 3 lists a sampling of ITS asset management goals and objectives from various agencies.

Table 3. Intelligent transportation systems asset management goals and objectives.

Agency	Goals and/or Objectives
Utah DOT[(42)]	Strategic goals: ■ Zero fatalities. ■ Optimize mobility. ■ Preserve infrastructure. Objectives of the TAMP: ■ Formalize a data-driven performance-based approach for allocating transportation funds to manage pavements, bridges, ATMS, and signal devices. ■ Incorporate asset management into the intermediate- and long-range planning processes. ■ Incorporate risk management into resource allocation decisions. ■ Provide a valuable asset management tool with dynamic data connections.
Georgia DOT[(23)]	Goals: ■ Maintain Georgia DOT's current ITS asset network. ■ Update and track all changes to the system. ■ To maintain highest possible operability of devices within its ITS maintenance assets. ■ Upgrade existing assets based on Georgia DOT's obsolescence plan. ■ Respond quickly to all device issues and downtimes. ■ Differentiate devices based on criticality.
Colorado DOT[(13]	Objective of ITS program: ■ Develop Statewide policies, procedures, and parameters on design, maintenance, life- cycle asset management, integration, and operation of traffic signal and ramp meters. ■ Manage various Statewide funding programs and pools. ■ Facilitate informed decision-making on project prioritization. Focus of ITS program: ■ Implement new and innovative technologies, including connected vehicle/autonomous vehicle applications, deploying and integrating Statewide ITS, incorporating automated performance measures, and extending technical resources to Colorado DOT Regions in the areas of traffic signal and ramp metering. ITS target for device capital replacement: ■ 90 percent of device useful life, which is calculated by dividing device age by device life-cycle.

Agency	Goals and/or Objectives
Caltrans9)	Goal: ▪ Safety and health (provide a safe transportation system for workers and users and promote health through active transportation and reduced pollution in communities). ▪ Stewardship and efficiency (money counts; responsibly manage California's transportation-related assets). ▪ Sustainability, livability, and economy (make long-lasting, smart mobility decisions that improve the environment; support a vibrant economy; and build communities, not sprawl). ▪ System performance (utilize leadership, collaboration, and strategic partnerships to develop ITS that provide reliable and accessible mobility for travelers). ▪ Organizational excellence (be a national leader in delivering quality service through excellent employee performance, public communication, and accountability). Statewide asset management performance objectives: ▪ TMS life-cycle health – 90 percent within expected life-cycle and functionally available. TMS uptime health – 90 percent TMS units functional.

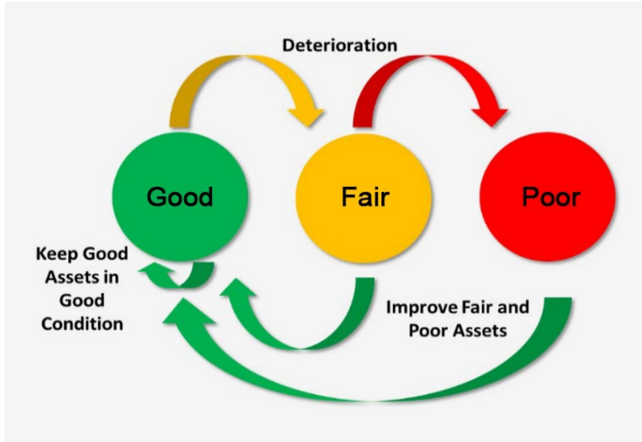
Source: Federal Highway Administration.

ATMS = advanced traffic management system, Caltrans= California Department of Transportation, DOT = department of transportation, ITS = intelligent transportation systems, TAMP = Transportation Asset Management Plan, TMS = transportation management system.

A fundamental objective for all agencies is to keep ITS devices in the good state of repair with optimal uptime to obtain optimal performance management.

Figure 1 represents the cycle of physical asset deterioration and improvement.[9] There are three potential performance management models that can be considered—Physical Asset, Deficiency, and Reservation.

The Physical Asset Model defines the methods and parameters needed to characterize how the condition of a physical asset will degrade over time. The Deficiency Model is used to measure progress towards addressing elements or locations identified through legal or strategic goal-driven requirements. The Reservation Model is applied to unanticipated or unplanned needs, primarily emergency response activities. Objectives using the Reservation Model cannot be predicted in terms of the quantity or location of need, as location and scope of needs are not known until an event (e.g., hurricane, flood, tornado, landslide, or other difficult-to-predict disaster) occurs.



Source: ©California Department of Transportation.

Figure 1: Graph. Deterioration and improvement cycle for physical assets.

Table 4 lists potential goals and objectives that an agency can adopt for ITS asset management and performance measurement.

Table 4. Intelligent transportation systems asset management and performance measurement goals and objectives.

Goals	Objectives
▪ Maximize the reliability, efficiency, and life-cycle costs of roadway assets. ▪ Ensure the effective operation of TMS.	▪ Maintain a greater than 90 percent uptime for all critical Tier 1 ITS devices (e.g., traffic detectors, traffic signals, communications devices, message signs, etc.). Definitions of the tiers are defined later in this chapter. ▪ Maintain a greater than 70 percent update for non-critical ITS devices (e.g., weather stations, highway advisory radios, etc.). ▪ 90 percent of ITS devices will operate with 90 percent of their life expectancy.

Source: Federal Highway Administration.

ITS = intelligent transportation systems, TMS = transportation management system.

Responsibilities

Part of the goals and objectives discussion is to assign responsibilities of staff to implement and meet the objectives. Roles are described in table 5.

Table 5. Roles and responsibilities.

Roles	Responsibilities
Asset Management Data Entry Personnel	Adding, editing, and searching assets in ITS asset management database.
Operators	Create ITS maintenance tickets, view tickets, close tickets, and view and review work orders.
Field Maintenance Personnel	View tickets, update ticket progress, advance tickets, close tickets, and issue work orders.
Inspectors	Review field tests and field test results; update work orders.
IT Administrators	Maintain asset management systems, services, network management systems, and data analytics tools.
TMC and Operations Managers	Review asset performance reports.
Contracts Personnel	Establish contracts for ITS asset management.
Asset Management Contractor	Maintain ITS field elements and communications, respond to and complete trouble tickets, and perform field testing.
TMS Software/Systems Integration Contractor(s)	Maintain central software and hardware components (non-typical ITS assets), respond to and complete trouble tickets, and perform systems testing.

Source: Federal Highway Administration.

IT = information technology, ITS = intelligent transportation systems, TMC = transportation management center, TMS = transportation management system.

Several agencies document and adopt asset management roles and responsibilities. Figure 2 is one example developed by the NYSDOT.[35]

TAM System: Roles and Permissions											
Permissions	Roles*										
	Data Entry Operator	Data Entry Manager	Data Entry Guest	Operator	Reviewer	Central	Field	TES Review	Inspector	EIC	Administrator
Add Assets	●	●									●
Edit Asset Data	●	●									●
View/Search Assets	●	●	●								●
Create New Ticket (Send to Reviewer for Issue)				●							●
Issue Tickets					●			●			●
View Tickets				●	●	●	●	●			●
Update Ticket Process						●	●	●			●
Move Tickets to Next Phase						●	●	●			●
Move Tickets to any Phase								●			●
Request Ticket Closure						●	●	●			●
Close Ticket				●	●						●
Issue Work Order								●			●
View Work Order				●	●	●	●	●	●	●	●
Update Work Order Progress								●	●	●	●
Retract Work Order								●			●
Reissue Work Order								●			●
Hold Work Order								●	●	●	●
Forward Work Order to Contractor								●	●	●	●
Request to Close Work order								●	●		●
Close Work Order								●		●	●
Add Users											●
Edit Users											●
Assign Users to Role											●
A user can be assigned to more than one role. For example: a user can be assigned a Reviewer role as well as a Data Entry Manager role. The user will then have the permissions applicable to Reviewer and Datab Entry Manager role.											

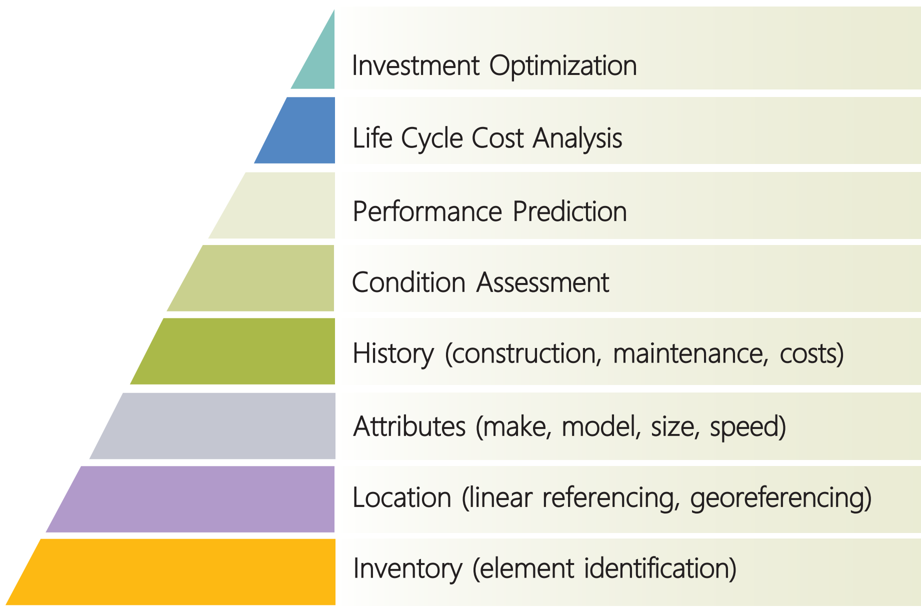
Source: ©New York State Department of Transportation.

Figure 2. Screenshot. Potential intelligent transportation systems asset management roles and responsibilities table.

IDENTIFY PERFORMANCE MEASURES/DATA REQUIREMENTS

To optimize the investment in ITS devices and roadways that they monitor and manage, agencies may perform specific actions that include conducting full asset inventories, identifying asset attributes, performing condition assessments, analyzing past history, performing life-cycle cost analysis, and performing asset predictions.

Figure 3 shows TAM as a pyramid, with the objective of investment optimization as the end primary objective.[38] The levels are generally consistent with the Federal TAMP requirements and are applicable to ITS assets as well as traditional transportation assets. However, the specific data and processes of each level can be very different due to the unique characteristics of ITS devices.



Source: ©South Dakota Department of Transportation.

Figure 3. Graph. Levels of asset management.

Identify Performance Measures and Data Sources

There are various ITS devices that can be monitored and maintained, including ITS field devices, communications equipment and media, servers, application software, and mobile assets. Table 6 lists the ITS devices that are tracked and monitored by agencies. This table is organized by asset class, asset type, and asset examples.[38]

Table 6. Intelligent transportation systems devices for tracking and monitoring.

Asset Types	Asset Examples
Cameras	■ Traffic. ■ Video detection. ■ License plate reader.
Connected and automated vehicle	■ Roadside units. ■ On-board units. ■ Antennas.

Asset Types	Asset Examples
Emergency call boxes	■ Call boxes.
Electronic clearance	■ Toll plazas. ■ Commercial vehicle ports.
Highway advisory radio	■ Broadcast units.
Message signs	■ Dynamic message signs. ■ Blank out/extinguishable message signs. ■ Variable speed limit/lane management signs.
Vehicle detectors	■ Inductive loops. ■ Magnetometers. ■ Microwave radar. ■ Doppler radar. ■ Video image processing. ■ Bluetooth/Wi-Fi sensors.
Other sensors	■ Commercial vehicle dimension. ■ Weigh in motion. ■ Roadway intersection conflict warning systems.
Road weather information systems	■ Stations.
Traffic control	■ Controllers. ■ Gates. ■ Lane control. ■ Pre-emption signals. ■ Ramp meters. ■ Reversible lane sign. ■ Signals. ■ Variable speed limits. ■ Warning flashers.
Traffic detection	■ Sensors.
Weigh in motion	■ Fixed. ■ Portable.
Communications media	■ Fiber. ■ Copper. ■ Radio/microwave.
Communication devices	■ Network switches. ■ Routers. ■ Radio transceivers. ■ Models.
Networking	■ Networking hardware. ■ Video equipment.
Video wall	■ Video wall displays/monitors. ■ Video wall controllers.

Asset Types	Asset Examples
Video distribution	▪ Video/media servers. ▪ Video encoder/decoders.
Servers	▪ Application servers. ▪ Database servers. ▪ Communication servers/front-end processors. ▪ On-site server facilities. ▪ On-site servers. ▪ Workstations.
State-owned, licensed, and cloud-based software	▪ Asset management. ▪ Connected vehicle. ▪ GIS/linear referencing systems. ▪ Maintenance decision support systems. ▪ Traffic management. ▪ Traveler information. ▪ Video management.
Mobile	▪ Probes (e.g., snowplows).
Portable	▪ Smart work zone. ▪ Arrow boards. ▪ Portable dynamic message signs, cameras, etc.

Source: Federal Highway Administration.

DMS=dynamic message sign, GIS=geographic information system.

Based upon the information that is being tracked by agencies that have established ITS device and performance measurement practices in place, the following are several of the voluntary performance measures being tracked for ITS assets:

- **Asset condition (e.g., good, medium, and poor)** – This can be calculated by comparing the age of a device against the manufacturer's estimated service life. It can also be a subjective assessment based upon the known device reliability, component testing, physical inspection, and known/observed component reliability.
- **Asset health/uptime/reliability** – Reliability of each type of ITS equipment/system can be determined by calculating the amount of time the equipment/system was malfunctioning compared to the total amount of time the equipment/system is operational for each month of the year. Time operational is given as a percentage of hours during each month that a particular system is functioning.
- **Mean time between failures** – This is the predicted elapsed time between inherent failures of a mechanical or electronic system, during normal system operation. It can be calculated as the arithmetic mean (average) time between failures of an asset.
- **Mean time to repair** – This is the basic measure of the maintainability of repairable items. It represents the average time required to repair a failed component or device. Expressed mathematically, it is the total corrective maintenance time for failures divided by the total number of corrective maintenance actions for failures during a given period of time.

- **Malfunction/issue type** – When trouble tickets are created associated with a device malfunction or failure, it can be beneficial to record the type of issue that is observed. For example, for a dynamic message sign (DMS), there are standard failure messages that can be detected with National Transportation of ITS Protocol 1203, including fan failure, pixel failure, over temperature alarm, etc. Knowing the frequently received failure can help with stocking parts and more quickly resolving issues.
- **Life-cycle costs, or whole-life costing** – This is the process of estimating how much money will be spent on an asset over the course of its useful life.

The Transportation Systems Management and Operations (TSMO) Capability Maturity Framework(17) is a tool used to improve the effectiveness of TSMO programs. It consists of six different dimensions: business processes, collaboration, systems and technology, organization and workforce, performance measurement, and culture. The tool allows agencies to assess their maturity in all six dimensions across four levels and to identify steps that will get them to the next maturity level, thus improving their program. Performance measurement, one of the key topics in this report, is also one of the Capability Maturity Model dimensions by which agencies can measure themselves. Benchmarking the agency's performance measurement maturity level and executing the steps that will move that agency to the next maturity level will help improve the agency's program.

As it relates to condition, ITS devices do not typically have a formally established performance metric. Table 7 is a sample simplified subjective performance metric used by Nevada DOT based on the manufacturers' recommended service life for each device.

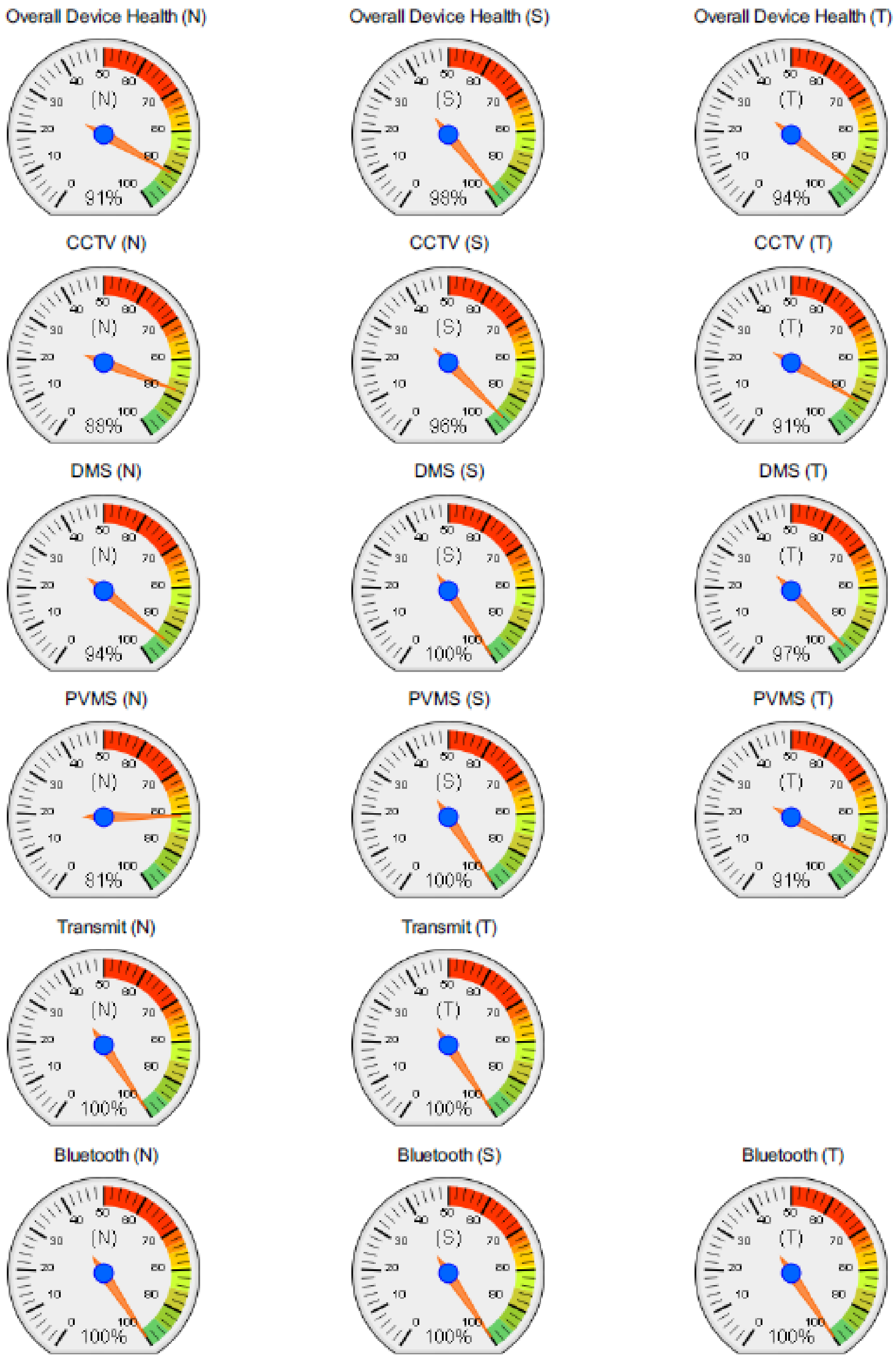
Table 7. Sample intelligent transportation systems condition rating scale.

Condition Category	Condition Description
Good	Age of the device is less than 80 percent of the manufacturer's recommended service life.
Low Risk	Age of the device is between 80 and 100 percent of the manufacturer's recommended service life.
Medium Risk	Age of the device is between 100 and 125 percent of the manufacturer's recommended service life.
High Risk	Age of the device is greater than 125 percent of the manufacturer's recommended service life.

Source: Nevada Department of Transportation.

Figure 4 is a sample report that reflects the devices that are tracked and how asset health can be displayed/reported.(34)

100%



Source: ©New Jersey Department of Transportation.

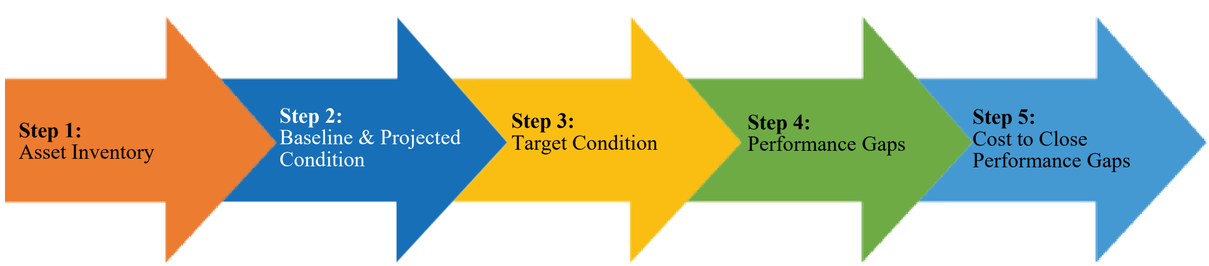
CCTV = closed-circuit television, DMS = dynamic message sign, PVMS = portable variable message sign, N = north, S = south, T = total.

Figure 4. Graph. Intelligent transportation systems asset health dashboard.

The sources for ITS asset health and performance metrics data are as follows:

- **TMS software** – Most agencies have advanced traffic management systems (ATMSs) that poll ITS devices at regular intervals to determine device health. This information is available in both real-time and in historical databases. These systems can be excellent sources of ITS asset performance information.
- **Network management system (NMS) tools** – Many agencies install NMS tools to monitor network components, such as switches, routers, and servers, in real-time and to send immediate alarms if there are any faults or problems. This is another excellent source of real-time and historic asset performance data.
- **Device/software error logs** – Both software and hardware systems contain internal logging functions to determine if systems have faults that are serious and need attention. Software, servers, databases, operating systems, and other components have such logging features as standard capabilities to help find and/or troubleshoot issues.
- **TAM system databases** – Many agencies have asset management tools and databases where ITS asset information is contained and updated. In many cases, specific staff are assigned the responsibility to create and maintain this information. A TAM system solution contains information on the age of a particular device and when and how often it has received routine or repair maintenance. It also denotes what type of maintenance activities occurred.
- **Configuration management plans** – Some agencies (e.g., California DOT [Caltrans]) develop configuration management plans that include schematics and details on how the end-to-end ITS system and network are wired and configured. This is fundamental information for the asset management database itself.
- **Maintenance management plans** – These plans detail what type of maintenance activities occur, how often they occur, and estimate the total level of effort for ITS asset maintenance (preventive, rehabilitation, and repair). Often, these documents help determine full life-cycle costs.
- **Construction databases** – When construction activities occur, new ITS devices are often installed and replaced. This information helps keep the ATMSs, NMS, and TAMs up to date.

A first step in appropriate asset management is to perform a complete asset inventory and identify what work and investment are needed to get ITS devices to the level of performance that is desired. Figure 5 represents the flow needed for this needs assessment, while table 8 describes the steps.[(9)]



Source: ©California Department of Transportation.

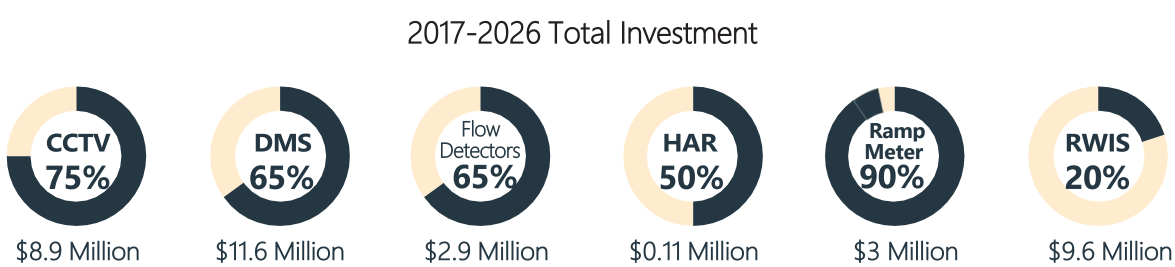
Figure 5. Graph. Needs assessment steps.

Table 8. Needs assessment step descriptions.

Asset Assessment Step	Description
Step 1. Complete Asset Inventory	Identify all of the assets, asset quantities, and key attributes.
Step 2. Baseline or Projected Condition	Flag the current condition of each asset as well as the projected future condition at the end of a prescribed period (e.g., 10 years). Current condition can be assigned based upon the percentage of the device's identified useful life and/or via inspection or testing.
Step 3. Target Condition	Set a target condition during or at the end of the performance period (e.g., "In 3 years, the system uptime will be 70 percent and in 5 years it will be 80 percent").
Step 4. Performance Gaps	Perform gap analysis to quantify the difference between the projected condition with pipelined projects/repair maintenance activities and the target desired state of repair condition at the end of the plan period.
Step 5. Costs to Close Gaps	Identify the costs to close the gaps. This can be calculated using the unit costs associated with bringing a device or system from poor or fair condition to good condition.

Source: California Department of Transportation

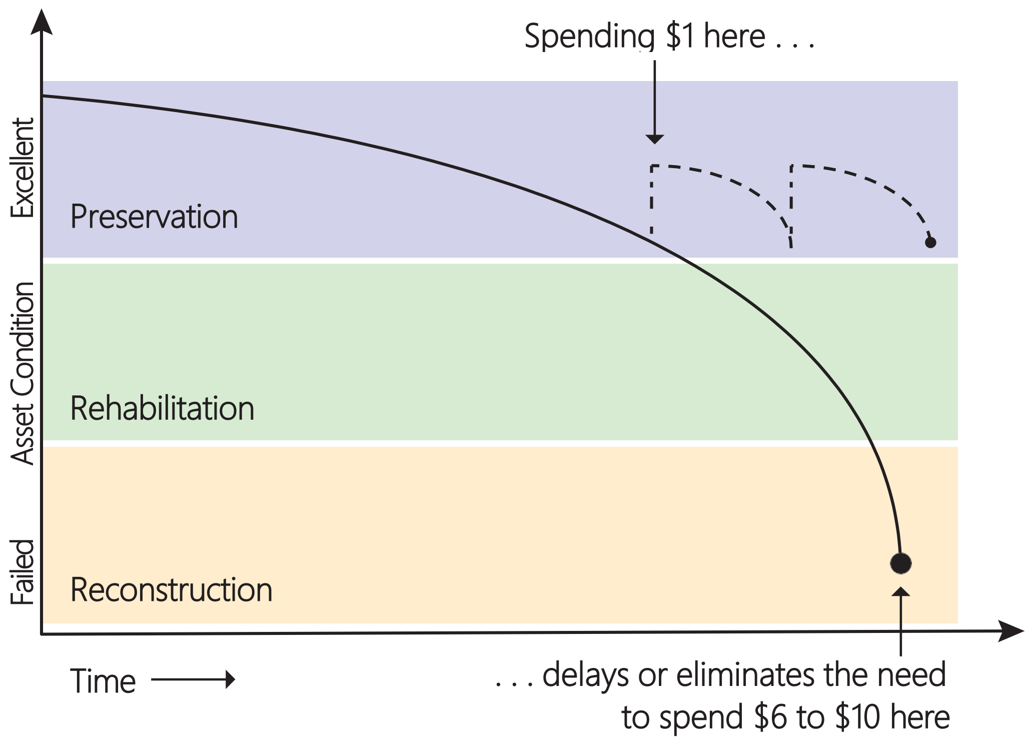
Figure 6 can be viewed as a graphical result from the needs assessment exercise.[31] Each device type or class is identified, along with its current uptime and the financial investment to meet the ultimate uptime/device health goal.



Source: ©Nevada Department of Transportation.

Figure 6. Graph. Current intelligent transportation systems asset conditions example.

Over time, a properly maintained ITS system will focus more on preservation and preventive maintenance than a system where devices go into a state of disrepair and failure. When the latter occurs, maintenance activities and, in certain cases, full replacement costs typically will be much higher. For example, a routine preventive maintenance activity for a CCTV camera is to check the housing pressure and ensure there are no housing leaks. If leaks develop or pressure is too low, dust and water can enter the housing and cause damage, which can result in the need for full camera replacement much earlier than the device's reported life expectancy. Figure 7 shows a conceptual illustration on how preventive maintenance activities help extend asset life at a fraction of the cost of more extensive treatments by keeping assets in good condition.[31]



Source: ©Nevada Department of Transportation.

Figure 7. Graph. Conceptual model of asset deterioration and treatment strategies.

Data Requirements and Framework

As it relates to asset management for pavement and bridges, FHWA requires specific information in TAMPs relating to asset condition, performance gaps, life-cycle planning, and investment strategies for these items (23 CFR 515.7 and 515.9). As a result, there is an industry surrounding traditional TAM that includes commercial software tools in a wide range of costs, as well as professional services for agencies. Similar to what has been done for pavement and bridges, this section discusses a framework for ITS asset management.

Part of this framework is the assignment of ITS assets into tiers where the highest tier assets are those with the most value in terms of receiving prioritized attention and funding. Three tiers are listed and are described below:

- Tier 1:
    - Asset is critical to operations.
    - Minimal downtime is allowed.
    - Measurement targets are identified and tracked in real-time.
    - Receive dedicated prioritized funding.
- Tier 2:
    - Asset is highly beneficial to system operations.
    - Device is repaired within reasonable timeframes.
    - Measurement targets are identified and tracked.

- Tier 3:
    - Asset is beneficial but not critical to system operations.
    - Item repaired or replaced when damaged or demonstrated degraded performance.

Table 9 is an example of assignment of ITS assets into three tiers. Agencies perform their own assignments, because certain devices could be viewed as lower or higher priority based upon the agency's concept of operations (e.g., some agencies have a higher use and need for highway advisory radio than others).

Table 9. Intelligent transportation systems asset tiers.

Tier 1	Tier 2	Tier 3
■ ATMS servers. ■ Database servers. ■ Communication servers. ■ Advanced traveler information servers. ■ ATMS software. ■ Primary communication media (e.g., truck fiber). ■ Vehicle detectors. ■ DMSs. ■ Primary communication hardware (Layer 3 hub switches). ■ Over-height vehicle detection systems. ■ Electronic clearance. ■ Traffic signal controllers. ■ Traffic signals heads and hardware.	■ CCTV surveillance cameras. ■ Road weather information systems. ■ Secondary communication media (e.g., branch fibers). ■ Video wall controllers. ■ Video monitors/projection units. ■ ATMS workstations. ■ Secondary communication hardware (e.g., Layer 2 switches and edge switches). ■ Ramp meters. ■ Automated license plate reader cameras.	■ Highway advisory radio. ■ Weigh in motion. ■ Emergency call boxes. ■ Portable signs. ■ Portable detectors. ■ Portable cameras. ■ Connected vehicle on-board units and roadside units.

Source: Federal Highway Administration.

ATMS = advanced traffic management systems, CCTV = closed circuit television, DMS = dynamic message signs.

Table 10 represents the data attributes that can be collected within the ITS asset management system/ tools and the recommended frequency at which this information can be collected. This is a lot of information, but these are the recommended attributes that can be collected, especially for devices that are critical to system operations. System monitoring tools are used to collect these data.

Table 10. Asset attribute collection frequency.

Asset	Attributes	Frequency
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Device make and model	Update once per year
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	System up/down	Once every 15 minutes
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Central processing unit metrics (utilization, ready, used, and wait)	Once every 15 minutes
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Memory metrics (utilization, overhead, shared, usage, swap-out, and swap-in)	Once every 15 minutes
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Network metrics (packets received, packets transmitted)	Once every 15 minutes
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Disk metrics (utilization, free, read/write rate, and read/write requests)	Once per hour
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Temperature	Once every 15 minutes
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Fan speed	Once every 15 minutes
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Power supply	Once every 15 minutes
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Processor clock speed	Once every 15 minutes
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Battery	Once per hour
ATMS Servers, Database Servers, Communication Servers, Advanced Traveler Information System Servers	Disk array	Once per hour
Communication Networking Hardware/Switches	Device availability	Once every 15 minutes
Communication Networking Hardware/Switches	Interface availability	Once every 15 minutes
Communication Networking Hardware/Switches	Wan link availability	Once every 15 minutes

Asset	Attributes	Frequency
Relational Database Software	System up/down availability	Once every 15 minutes
Relational Database Software	Memory and central processing unit utilization	Once every 15 minutes
Relational Database Software	Locks	Once every 15 minutes
Relational Database Software	Indexes	Once every 15 minutes
Relational Database Software	Buffer and cache	Once every 15 minutes
Relational Database Software	SQL queries	Once every 15 minutes
Relational Database Software	Replication details	Once every 15 minutes
Relational Database Software	Jobs and sessions details	Once every 15 minutes
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Hardware version	Update once per year (or as updates occur)
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Firmware version	Update once per year (or as updates occur)
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Communication protocol	Update once per year (or as updates occur)
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Device up/down availability	Once every 5 minutes
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Over temperature alarms	Once every 5 minutes
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Humidity alarms	Once every 5 minutes
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Pixel/lamp errors	Once every 5 minutes
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Power errors	Once every 5 minutes
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Communication errors	Once every 5 minutes
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Fan alarms	Once every 5 minutes
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Equipment repair date	When activity occurs
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Equipment repair description	When activity occurs
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Equipment update date	When activity occurs
DMSs, Variable Speed Limit Signs, Dynamic Lane Management Signs	Equipment update description	When activity occurs
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Device make and model	Update once per year (or as updates occur)
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Firmware version	Update once per year (or as updates occur)
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Device up/down availability	Once every 5 minutes

Asset	Attributes	Frequency
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Over temperature alarms	Once every 5 minutes
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Humidity alarms	Once every 5 minutes
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Housing pressure level	Once every 5 minutes
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Power errors	Once every 5 minutes
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Communication errors	Once every 5 minutes
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Wiper status	Once every 5 minutes
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Pan, tilt, and zoom status	Once every 5 minutes
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Equipment repair date	When activity occurs
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Equipment repair description	When activity occurs
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Equipment update date	When activity occurs
CCTV Surveillance Cameras, Automated License Plate Reader Cameras, Video Analytics Cameras	Equipment update description	When activity occurs
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Device make and model	Update once per year (or as updates occur)
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Hardware version	Update once per year (or as updates occur)
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Firmware version	Update once per year (or as updates occur)
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Communication protocol	Update once per year (or as updates occur)
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Device up/down availability	Once every 5 minutes
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Over temperature alarms	Once every 5 minutes
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Humidity alarms	Once every 5 minutes
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Short diagnostics message	Once every 5 minutes

Asset	Attributes	Frequency
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Long diagnostics message	Once every 5 minutes
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Power errors	Once every 5 minutes
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Communication errors	Once every 5 minutes
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Equipment repair date	When activity occurs
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Equipment repair description	When activity occurs
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Equipment update date	When activity occurs
Vehicle Detectors (radar, video image, inductive loop, and magnetometer)	Equipment update description	When activity occurs
Traffic Signals (controllers) and Hardware Ramp Meters	Device make and model	Update once per year (or as updates occur)
Traffic Signals (controllers) and Hardware Ramp Meters	Hardware version	Update once per year (or as updates occur)
Traffic Signals (controllers) and Hardware Ramp Meters	Firmware version	Update once per year (or as updates occur)
Traffic Signals (controllers) and Hardware Ramp Meters	Communication protocol	Update once per year (or as updates occur)
Traffic Signals (controllers) and Hardware Ramp Meters	Device up/down availability	Once every 5 minutes
Traffic Signals (controllers) and Hardware Ramp Meters	Over temperature alarms	Once every 15 minutes
Traffic Signals (controllers) and Hardware Ramp Meters	Humidity alarms	Once every 15 minutes
Traffic Signals (controllers) and Hardware Ramp Meters	Diagnostics message	Once every 15 minutes
Traffic Signals (controllers) and Hardware Ramp Meters	Power errors	Once every 15 minutes
Traffic Signals (controllers) and Hardware Ramp Meters	Communication errors	Once every 15 minutes
Traffic Signals (controllers) and Hardware Ramp Meters	Lamp/led status	Once every 15 minutes
Traffic Signals (controllers) and Hardware Ramp Meters	Controller alarm states	Once every 5 minutes
Traffic Signals (controllers) and Hardware Ramp Meters	Equipment repair date	When activity occurs
Traffic Signals (controllers) and Hardware Ramp Meters	Equipment repair description	When activity occurs
Traffic Signals (controllers) and Hardware Ramp Meters	Equipment update date	When activity occurs
Traffic Signals (controllers) and Hardware Ramp Meters	Equipment update description	When activity occurs
Road Weather Information Systems	Device make and model	Update once per year (or as updates occur)

Asset	Attributes	Frequency
Road Weather Information Systems	Hardware version	Update once per year (or as updates occur)
Road Weather Information Systems	Firmware version	Update once per year (or as updates occur)
Road Weather Information Systems	Communication protocol	Update once per year (or as updates occur)
Road Weather Information Systems	Device up/down availability	Once every 60 minutes
Road Weather Information Systems	Weather sensor status (individual)	Once every 60 minutes
Road Weather Information Systems	Diagnostics messages	Once every 60 minutes
Road Weather Information Systems	Power errors	Once every 60 minutes
Road Weather Information Systems	Communication errors	Once every 60 minutes
Road Weather Information Systems	Controller alarm states	Once every 60 minutes
Road Weather Information Systems	Equipment repair date	When activity occurs
Road Weather Information Systems	Equipment repair description	When activity occurs
Road Weather Information Systems	Equipment update date	When activity occurs
Road Weather Information Systems	Equipment update description	When activity occurs
Highway Advisory Radio	Device make and model	Update once per year (or as updates occur)
Highway Advisory Radio	Hardware version	Update once per year (or as updates occur)
Highway Advisory Radio	Firmware version	Update once per year (or as updates occur)
Highway Advisory Radio	Communication protocol	Update once per year (or as updates occur)
Highway Advisory Radio	Transmitter up/down availability	Once every 60 minutes
Highway Advisory Radio	Beacon status (up/down)	Once every 60 minutes
Highway Advisory Radio	Diagnostics messages	Once every 60 minutes
Highway Advisory Radio	Power errors	Once every 60 minutes
Highway Advisory Radio	Communication errors	Once every 60 minutes
Highway Advisory Radio	Controller alarm states	Once every 60 minutes
Highway Advisory Radio	Equipment repair date	When activity occurs
Highway Advisory Radio	Equipment repair description	When activity occurs
Highway Advisory Radio	Equipment update date	When activity occurs
Highway Advisory Radio	Equipment update description	When activity occurs
Video Wall Controller	Device make and model	Update once per year
Video Wall Controller	Software/firmware version	Update once per year
Video Wall Controller	System up/down	Once per day
Video Wall Controller	Central processing unit metrics (utilization, ready, used, and wait)	Once per day
Video Wall Controller	Memory metrics (utilization, overhead, shared, usage, swap-out, and swap-in)	Once per day
Video Wall Controller	Network metrics (packets received, packets transmitted)	Once per day

Asset	Attributes	Frequency
Video Wall Controller	Disk metrics (utilization, free, read/write rate, and read/write requests)	Once per day
Video Wall Controller	Temperature	Once per day
Video Wall Controller	Fan speed	Once per day
Video Wall Controller	Power supply	Once per day
Video Wall Controller	Equipment repair date	When activity occurs
Video Wall Controller	Equipment repair description	When activity occurs
Video Wall Controller	Equipment update date	When activity occurs
Video Wall Controller	Equipment update description	When activity occurs
Video Monitors/ Displays	Device make and model	Update once per year (or as updates occur)
Video Monitors/ Displays	Hardware version	Update once per year (or as updates occur)
Video Monitors/ Displays	Monitor up/down availability	Once per day
Video Monitors/ Displays	Equipment repair date	When activity occurs
Video Monitors/ Displays	Equipment repair description	When activity occurs
Video Monitors/ Displays	Equipment update date	When activity occurs
Video Monitors/ Displays	Equipment update description	When activity occurs
Emergency Call Boxes	Device make and model	Update once per year (or as updates occur)
Emergency Call Boxes	Hardware version	Update once per year (or as updates occur)
Emergency Call Boxes	Device up/down availability	Once per month
Emergency Call Boxes	Equipment repair date	When activity occurs
Emergency Call Boxes	Equipment repair description	When activity occurs
Emergency Call Boxes	Equipment update date	When activity occurs
Emergency Call Boxes	Equipment update description	When activity occurs

Source: Federal Highway Administration.

ATMS = advanced traffic management system, CCTV = closed-circuit television, DMS = dynamic message sign.

Process and Strategies

There are various examples related to processes and procedures to prioritize data and meet ITS asset management goals and objectives. The following describes these examples.

Centralize intelligent transportation systems asset information.

Some agencies store ITS asset information across multiple locations, such as location and status in an ATMS and condition and history in maintenance tracking software. This can result in difficulty in aggregating data for analysis and in conflicts when the multiple sources are not all up to date. It is recommended that agencies centralize their ITS asset information by developing interfaces to other systems that contain and use ITS asset information, such as ATMS, maintenance decision support system, and geographic information system (GIS), to allow for uniform information across systems.

Use intelligent transportation systems asset information in operations.

Some agencies include operations-specific information in their ITS asset management database, such as the status of devices (i.e., whether a sign or camera is currently operational). Additionally, utility and contact information can be included as it relates to field devices that have stopped communicating so that office and field staff can identify and contact the appropriate local power and communications providers. ATMS solutions can integrate real time asset management data within their algorithms, event management solutions, response plans, and decision support systems. For example, travel time algorithms can ignore inoperable vehicle detectors as part of their calculations. Similarly, decision support system solutions can disallow use of inoperable message signs and signals as part of its response plan recommendations.

Establish intelligent transportation systems asset management contracts.

To maintain ITS devices at the desired performance level, it is recommended that agencies create contracts to maintain ITS devices, including performing routine and emergency repair maintenance, or perform those functions in-house. Georgia DOT established asset maintenance contracts with disincentive payments if devices are not maintained correctly.

Figure 8 represents an example of how Georgia DOT pays its contractors for CCTV device maintenance.

		BASE PAYMENT		
CCTV	95%	80% of total device payout for each day < 95% operation	70% of total device payout for each day < 90% operation	60% of total device payout for each day < 80% operation
		PERFORMANCE PAYMENT		
		The Department will pay 103% of the monthly routine maintenance amount for each day that the level of service exceeds 97% of the Department will pay 105% of the monthly routine maintenance amount for each day that the level of service exceeds 99%. The Consultant shall be eligible for only the higher amount as appropriate.		
		NON-PERFORMANCE DEDUCTION FOR CRITICAL DEVICES		
		The Department's goal is to ensure that the SYSTEM functions effectively. To assist in achieving this goal the Department will deduct $500 each day (over 48 hours) for the Consultant's failure to repair each Critical CCTV within 48 hours. See **Exhibit 4 – Critical Devices** for locations.		
		NON-PERFORMANCE DEDUCTION FOR NON-CRITICAL DEVICES		
		The Department's goal is to ensure that the SYSTEM functions effectively. To assist in achieving this goal the Department will deduct $200 each day (over 30 calendar days) for the Consultant's failure to repair each Non-Critical CCTV within 30 calendar days.		

Source: ©Georgia Department of Transportation.

Figure 8. Screenshot. Example disincentive/incentive intelligent transportation systems asset maintenance schedule.

Manage intelligent transportation systems assets differently than other transportation assets.

Treating ITS assets as agencies treat pavement and bridges potentially limits capturing data relevant to ITS assets. An alternate approach is to recognize ITS assets, like information technology (IT) assets, by their characteristics and attributes such as:

- Software/firmware updates.
- Component-swappable.
- Dependence on communications and power for operation.
- Obsolescence from technological advance or lack of technical support.
- Security concerns.

It may be possible to more accurately assess the performance, maintenance, and life-cycles of ITS assets by managing them like IT. IT assets are considered to "rapidly depreciate and require constant update and replacement." They require a strategy that covers their entire life-cycle, including not only replacement but upgrades, continual improvement, and awareness of the impact of moving the assets or changing the external resources upon which their operations rely.

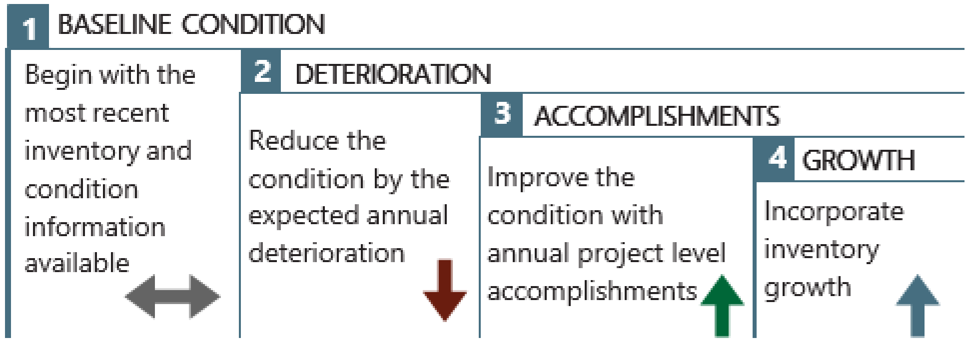
While the physical condition of a TSMO asset is critical, the impact to system performance must be considered. Operating TSMO assets may involve activities beyond its physical features and cover functionality. Improving TSMO assets may potentially include activities equivalent to reconstruction, as in pavements and bridges, but not necessarily as a result of poor asset condition. For example, this may include replacing technology-based assets that are obsolete. This may also apply to upgrades in existing technology, even if they are in good physical condition, to meet the current demand of the transportation system so that there is net benefit to system performance.

Use staff knowledge to identify issues.

Agencies can look to use their own staff experience as a reliable source for assessing the health of their ITS devices. In particular, State DOTs said they had great success in involving field staff in identifying health issues, such as the performance of specific devices or components. For example, the field staff may be the first to identify that a particular type of battery performs poorly under certain environmental conditions, or that a wireless communications medium does not meet the requirements in a certain area due to poor coverage.

Develop an investment plan.

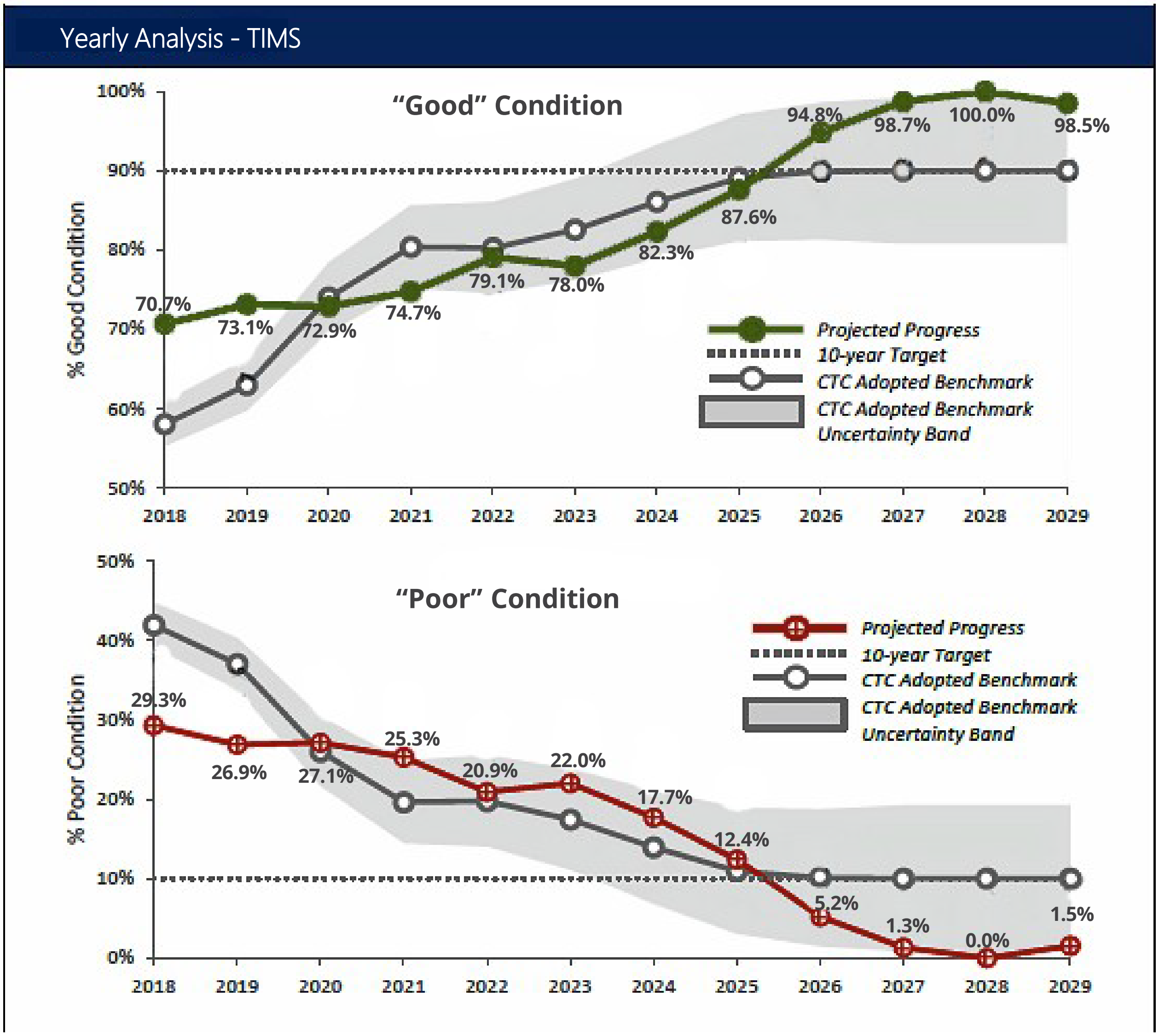
Once an agency has a baseline asset inventory with an assessment of the condition of these elements, an investment plan can be created to get these assets to their desired condition or to keep at the condition needed to maintain the identified performance benchmarks. A calculation framework that relies on the initial baseline inventory and condition data, deterioration models, and project-level accomplishments for all work completed within the 10-year performance period can provide helpful information. Figure 9 represents Caltrans' four-step calculation method, which is carried out for each year's performance to determine anticipated asset conditions.(9)



Source: ©California Department of Transportation.

Figure 9. Graph. Four-step projection calculation method.

Figure 10 represents a 10-year example project of asset condition based upon allocated or projected investment levels.(9)



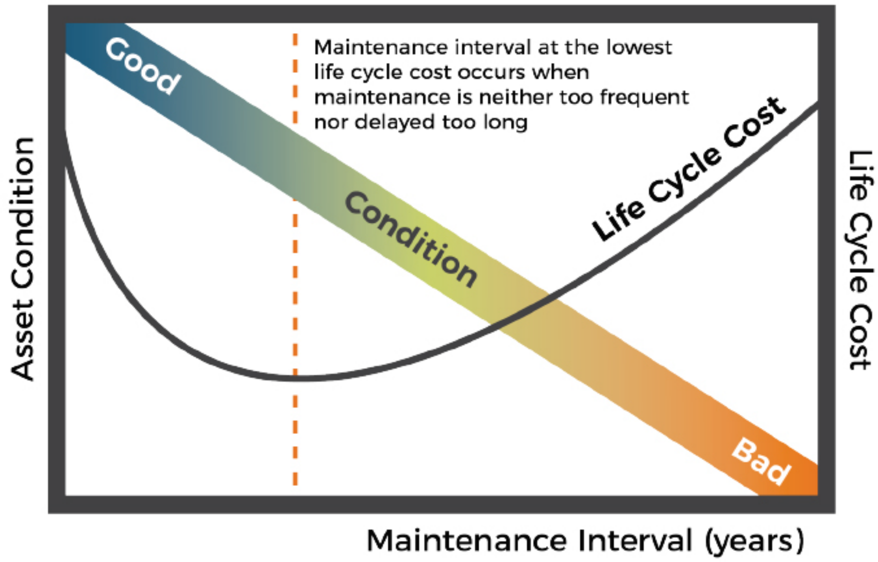
Source: ©California Department of Transportation.

Figure 10. Graph. Intelligent transportation systems asset benchmark projection.

Perform life-cycle planning.

Several agencies conduct life-cycle planning (LCP) analysis for their ITS devices, an important step in asset management. LCP analysis considers, at a network level, the numerous costs associated with construction, inspection, maintenance, rehabilitation, and disposal (or retirement) once the service life of the asset has ended. In an LCP analysis, the near-term cost of timely preservation, repair, or maintenance action is balanced against the benefit of delaying larger costs farther into the future.

A key goal of an LCP analysis is to find the level of improvement and preservation where life-cycle costs are minimized. Conceptually, this "happy medium" point (illustrated in Figure 11) exists where maintenance expenditures are neither too frequent nor delayed too long.(31)

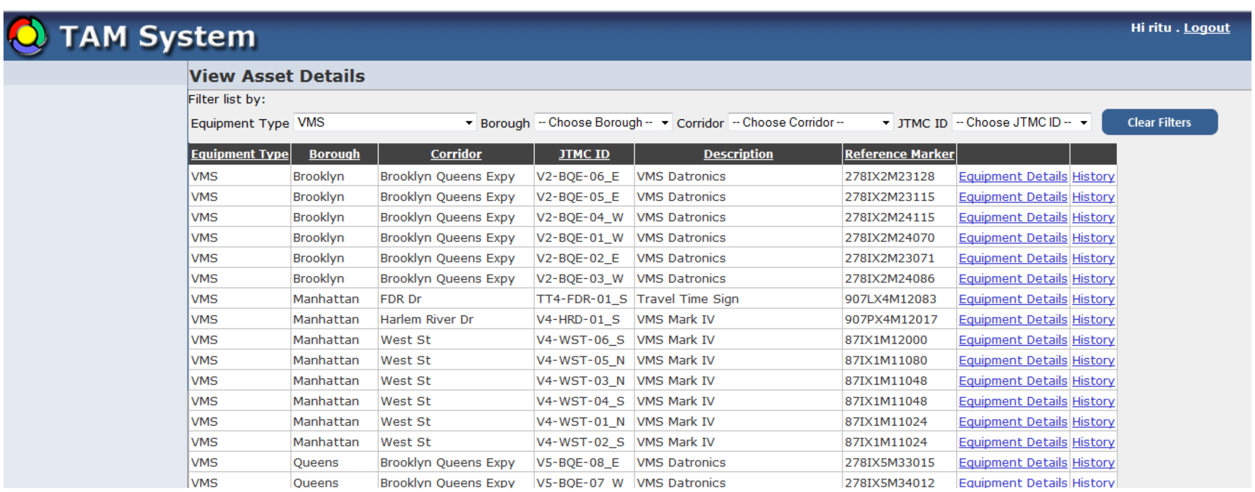


Source: ©Nevada Department of Transportation.

Figure 11. Graph. Life-cycle cost analysis concept.

Install network management system and/or performance monitoring tools.

Agencies can procure, install, and maintain NMS tools and/or performance monitoring tools. These types of tools automate the process to check asset health, store this information in a database, and provide automated dashboards and analytics on the condition of assets. Figure 12 is from NYSDOT's asset management tools used to track the conditions of all ITS assets.(36)



Equipment Type	Borough	Corridor	JTMC ID	Description	Reference Marker		
VMS	Brooklyn	Brooklyn Queens Expy	V2-BQE-06_E	VMS Datronics	278IX2M23128	Equipment Details	History
VMS	Brooklyn	Brooklyn Queens Expy	V2-BQE-05_E	VMS Datronics	278IX2M23115	Equipment Details	History
VMS	Brooklyn	Brooklyn Queens Expy	V2-BQE-04_W	VMS Datronics	278IX2M24115	Equipment Details	History
VMS	Brooklyn	Brooklyn Queens Expy	V2-BQE-01_W	VMS Datronics	278IX2M24070	Equipment Details	History
VMS	Brooklyn	Brooklyn Queens Expy	V2-BQE-02_E	VMS Datronics	278IX2M23071	Equipment Details	History
VMS	Brooklyn	Brooklyn Queens Expy	V2-BQE-03_W	VMS Datronics	278IX2M24086	Equipment Details	History
VMS	Manhattan	FDR Dr	TT4-FDR-01_S	Travel Time Sign	907LX4M12083	Equipment Details	History
VMS	Manhattan	Harlem River Dr	V4-HRD-01_S	VMS Mark IV	907PX4M12017	Equipment Details	History
VMS	Manhattan	West St	V4-WST-06_S	VMS Mark IV	87IX1M12000	Equipment Details	History
VMS	Manhattan	West St	V4-WST-05_N	VMS Mark IV	87IX1M11080	Equipment Details	History
VMS	Manhattan	West St	V4-WST-03_N	VMS Mark IV	87IX1M11048	Equipment Details	History
VMS	Manhattan	West St	V4-WST-04_S	VMS Mark IV	87IX1M11048	Equipment Details	History
VMS	Manhattan	West St	V4-WST-01_N	VMS Mark IV	87IX1M11024	Equipment Details	History
VMS	Manhattan	West St	V4-WST-02_S	VMS Mark IV	87IX1M11024	Equipment Details	History
VMS	Queens	Brooklyn Queens Expy	V5-BQE-08_E	VMS Datronics	278IX5M33015	Equipment Details	History
VMS	Queens	Brooklyn Queens Expy	V5-BQE-07_W	VMS Datronics	278IX5M34012	Equipment Details	History

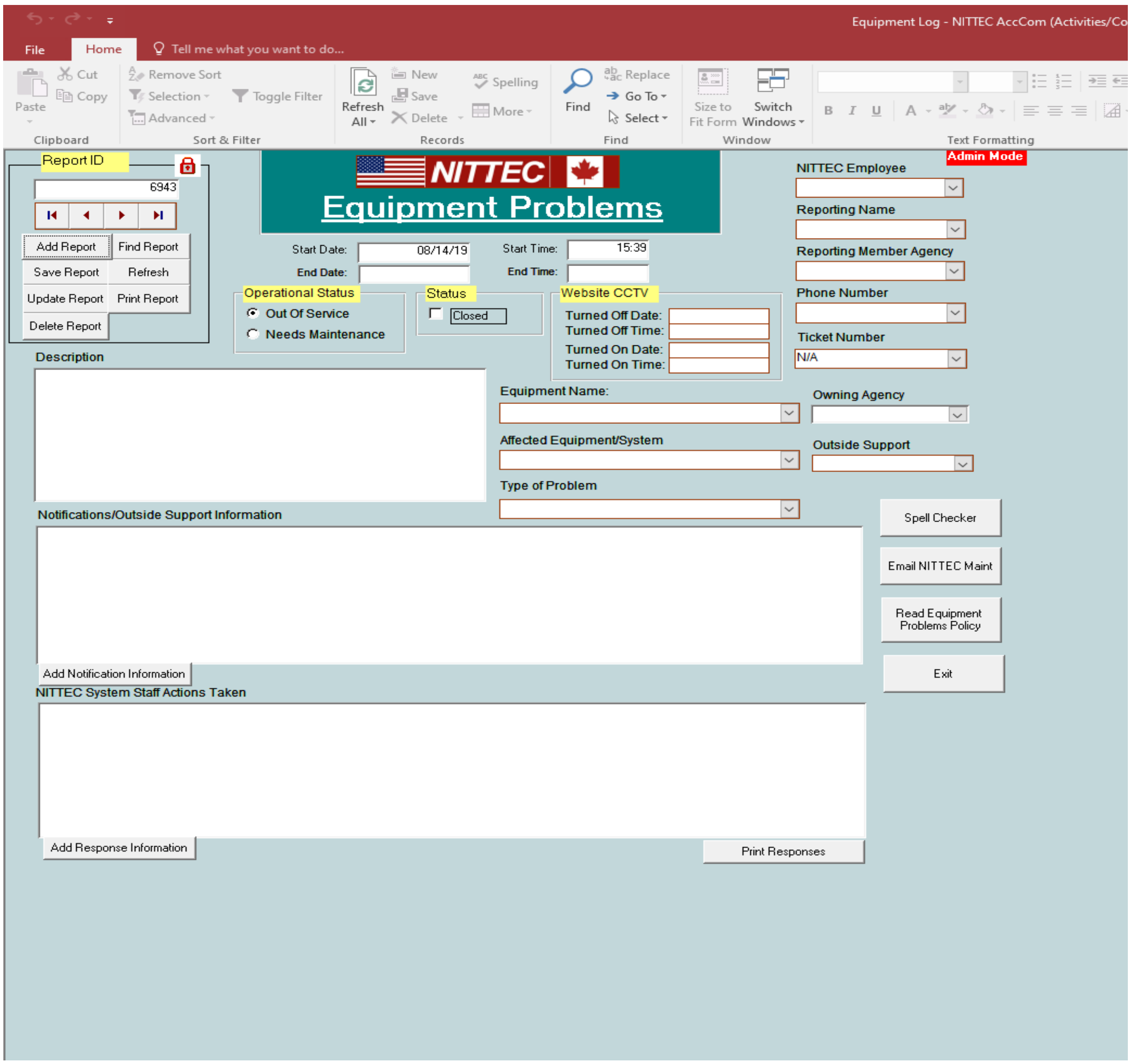
Source: ©New York State Department of Transportation.

Figure 12. Screenshot. Example asset management screen.

Implement maintenance trouble ticket systems.

Agencies can consider implementing on-line ITS asset trouble ticket systems to report system issues (e.g., system malfunctions, necessary repairs, etc.) so they can be repaired quickly and specifics of the repair itself (e.g., time to repair) are tracked. These can be on-line, off-the-shelf tools; open-source tools; or custom-built tools. These tools are also called maintenance on-line management systems.

Figure 13 is a sample screen from the Niagara International Transportation Technology Coalition (NITTEC) on-line trouble ticket system.[37]



Source: ©Niagara International Transportation Technology Coalition.

Figure 13. Screenshot. Intelligent transportation systems asset repair order.

Develop an obsolescence plan/emerging technology plan.

Some agencies have developed an obsolescence plan, which includes information on how agencies investigate and introduce emerging technologies to replace aging ITS infrastructure. One example is to use traffic probe data to replace older aging roadway vehicle detection sensors. Another example is replacing intrusive vehicle detectors with newer non-intrusive ones, which are lower cost to maintain in the long term.

Georgia DOT is one agency that develops these emerging technology plans. The plan is viewed as a key component in managing the aging ITS infrastructure and ensuring the network of equipment remains useful, with continuing enhancements to allow effective traffic management now and into the future. Georgia DOT uses the following five-step plan:

1. **Define the new technology strategy** – In this critical first step, the plan describes how the emerging technology fits into the Department's goals by identifying a vision and objectives that set the groundwork for the next steps.

2. **Identify requirements** – After the vision and need for new technology are defined, a comprehensive set of requirements is defined by describing the scope of the Department's needs and specifications and evaluating the current technology being used.

3. **Design, develop, scope, and procure technology** – During this step, procedures involved in the procurement and development of technology are outlined based on the requirements outlined in Step 2.

4. **Implement and train** – Once the emerging technology is installed in a test location, it is monitored for operation and compatibility. This step also involves increasing awareness among employees about the availability of the new technology and training technicians on installation, troubleshooting, and repairs.

5. **Test results maintain technology and continue learning** – In the last step, Georgia DOT reviews test results, evaluates review results, and provides recommendations.

Coordinate with Other Departments and Agencies

With State and local ITS performance measures and data requirements identified and processes and strategies defined, the ITS organization then coordinates with other departments or agencies to obtain the data required to measure performance for ITS Asset Management Plan analysis purposes. ITS systems typically generate or collect a wealth of data to support development of optional performance measures for transportation system operations, and the information can be sourced internally with the ITS department. However, data collected using ITS can be coordinated through another department such as the agency's operations department, which manages the TMC. If the agency does not have a TMC, data collection can be coordinated from a regional source such as a metropolitan planning organization or another adjacent agency.

TSMO plans are data-driven. A TSMO plan, typically developed within an operations department, serves as a road map to guide the State DOTs as they continue to integrate operations, asset management, and preservation into the organization. ITS devices provide enriched data sets; enable better analysis and implementation of TMSO strategies; and support robust, defensible decision-making. As an example, accurate and reliable roadway sensor data can enable the deployment of a ramp metering system. Therefore, coordination between the ITS group and the operations department is a critical element in the success of the ITS asset management plan.

Beyond coordination related to data requirements and performance evaluation, the ITS Asset Management Plan information can be fed into the State DOT's overall TAMP documents. The ITS group can provide the ITS Asset Management Plan project information to the asset management department for inclusion in the State DOTs TAMP. Once included within the overall TAMP, this information can be provided to the State DOTs planning and programming department and the finance department. Typically, the planning and programming department assembles project information from all departments that relate to the capital and maintenance programs, and then provides this information to the finance group for aggregation and budgetary approvals from agency senior management.

Because ITS assets are competing against other agency assets for scarce capital resources, the ITS organization may seek assistance from the finance department to develop cost/benefit analysis for the various recommended projects. If this occurs early in the ITS project development process, it can ensure that only those projects that show the highest cost/benefit ratio are presented within the ITS Asset Management Plan documents.

The routine, periodic, and preventive maintenance associated with ITS devices should form a portion of the agency's ITS Asset Management Plan. In addition to the capital information generated from the ITS Asset Management Plan, the maintenance plans should be coordinated through the agency's maintenance management system for inclusion in the maintenance department's budget. Because ITS maintenance may require specialized equipment, materials, and training, some agencies elect to outsource this maintenance, as it can be more cost-effective. Coordination with the maintenance department is, therefore, an important part of the overall ITS Asset Management Plan program.

CHAPTER 4. DEVELOP A PLAN FOR PERFORMANCE DATA MANAGEMENT

ITS asset management is in the early stages within transportation agencies. While many agencies have plans for traditional transportation assets, such as pavement and bridges, very few have plans for the management of ITS assets. According to the Federal Highway Administration (FHWA) website, the goal of asset management is to "provide a desired level of service and performance for various assets within the transportation network, in a most cost-effective manner."(15) Large amounts of ITS data are currently collected, but the analysis, presentation, and dissemination of these data are generally not organized, and agencies may have a difficult time maintaining a high level of service when it comes to maintaining assets. Agencies that have successful ITS device and performance data management processes have one thing in common—a comprehensive performance data management plan. This chapter discusses additional information for reporting, visualizing, and managing ITS asset and performance data to provide better information for making more-informed decisions.

DATA MANAGEMENT

As identified in chapter 3, ITS generate and collect large amounts of transportation data. The careful planning of the data collection, storage, archiving, analysis, and dissemination will provide for more-effective performance management visualizations. Some key information to consider regarding the management of data are described in table 11.(37)

Table 11. Data management considerations.

Data Attribute	Description
Data Collection/Storage	It is best to standardize the collection throughout the agency so the development of the visualizations will be easier. Adequate storage that is made available can accommodate future growth, such as the addition of connected vehicle data. The key characteristics to collect regarding ITS devices include location, physical attributes, and current condition.
Data Archive	The archiving of data provides for historical information that would otherwise not be available. Archived data can help with before/after studies or provide analysis over a longer period of time. Key factors to consider include what to archive and the length of time to keep the archive. Retaining all data indefinitely could be cost prohibitive. Consider costs of storage, both physical and in the Cloud, when determining what and how long to archive the data.
Data Accuracy/ Completeness	An analysis is only as good as the data that went into the analysis. To be able to generate meaningful performance measurement data, it is important that the data collected be accurate and complete. If the quality of the data is poor, or much of the data is missing, accurate performance measures will be difficult to obtain. Determine tolerance levels for the completeness and accuracy of the data. Work to fix the deficiencies.

Data Attribute	Description
Reporting/ Dissemination	To be effective, the information generated should be put in a meaningful report and disseminated regularly. Determine the frequency of the reporting, what needs to be disseminated, and who the audience is. Modern visualization tools are capable of disseminating reports via email or updating a website dashboard in near real-time. When data access is readily available, more informed decisions can be made.

Source: Federal Highway Administration.

ITS = intelligent transportation system.

DATA VISUALIZATION USING MAPS

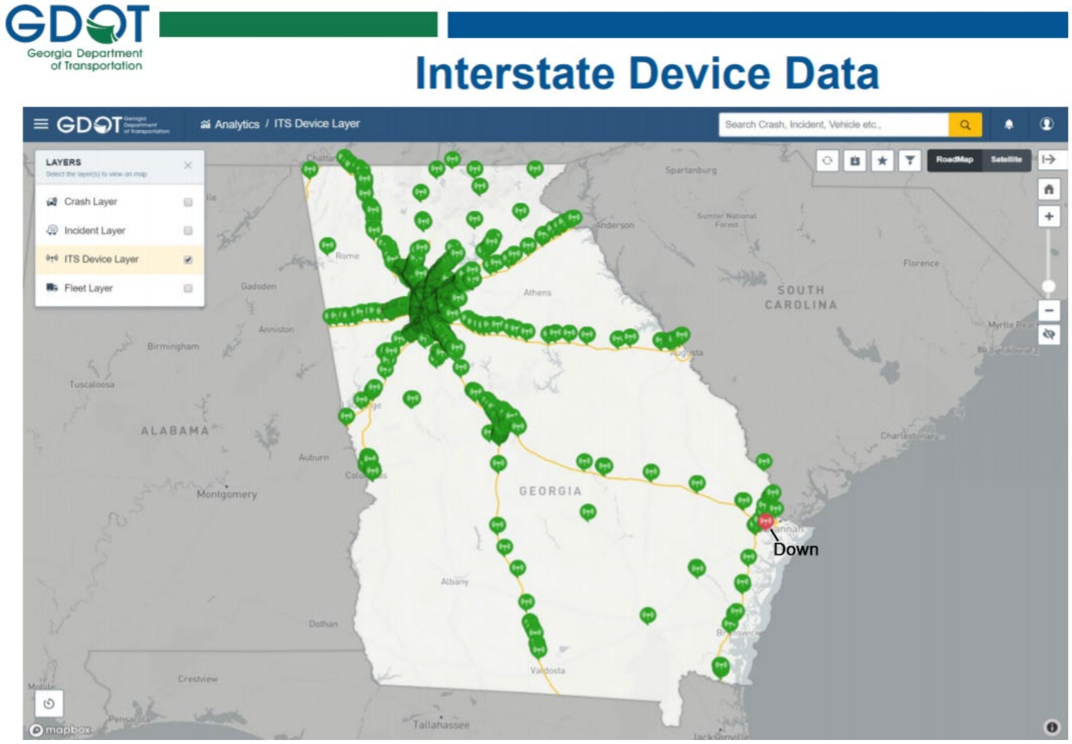
Using maps to display system data provides an analyst with a quick and easy way to determine the status of an ITS asset. As most ITS devices have a physical location (latitude/longitude), this information can be easily displayed on a geographic information system (GIS)-based map. For example, any ITS device can be represented by an icon on the map to easily see its location. Different icons can be used to represent different device types. The icon can be color coded to display its current status. Additional information, such as a work order number or work order status, can be displayed. Table 12 describes the more common map types used in data visualization.(12)

Table 12. Map visualization descriptions.

Map Type	Description
Point	Data contain a wide distribution of geographic information.
Line	Data contain routes such as a distribution route.
Regional	Data contain information from different regions.
Flow	Data contain origin-destination data, such as aviation routes.
Heat	Data contain quantitative values in an ordered field; color is often used to display the weight of each point.
Heat point	A more comprehensive display of the heat map, where each data point is a circle on the map.
Time space distribution	Used in Global Positioning System tracking; can be used for trajectory distribution.
Data space distribution	Used to arrange operation; can show traffic volume along a route.
Three-dimensional rectangle	Similar to the point map, but in three dimensions; points can be shown as three-dimensional objects.

Source: Federal Highway Administration.

Example map visualizations are included to display the types of map data visualizations that are currently in use. In Figure 14, the Georgia Department of Transportation (GDOT) uses a point map to display system-wide interstate device data.(21)



Source: ©Georgia Department of Transportation.

Figure 14. Screenshot. Point map of device data.

The U.S. Department of Transportation (USDOT) uses a point map for basic safety messages (Figure 15).(43)

Source: U.S. Department of Transportation.

Figure 15. Screenshot. Point map of basic safety messages.

DATA VISUALIZATION

Data visualization is an important piece of an ITS Asset Management Plan. While data visualization is not required, it functions as an important communication tool. It provides for the representation of data using graphs, charts, maps, or other tools. With visualization, large amounts of data can be analyzed quickly using colors or patterns. By using easy-to-distinguish attributes, such as sizes, colors, shapes, or filters, data can be presented for easy differentiation at a glance. Individual data sets can be combined to provide a more-effective analysis. Instead of reviewing different documents with row after row of spreadsheet data, with data visualization, an analyst can view a chart, map, or graph to quickly determine patterns or outliers. Table 13 describes the more common types of charting available, along with the best type of data for the chart.[(25)]

Table 13. Data visualization descriptions.

Type	Description
Geographic maps	Data where specific locations (latitude/longitude) are relevant.
Bar charts	Data contain at least one quantitative dimension.
Line graphs	Data contain one or more quantitative variables that are available, or where data can show change over time.
Pie charts	Data contain between five to eight slices (categories), totaling 100 percent of the data.
Flow charts	Data contain quantitative values associated with start and end points.
Heat maps	Data contain quantitative values in an ordered field.
Scatterplots	Data contain at least two quantitative values, each one on a different axis.
Pictographs	Simple data where a pictograph shows how many items there are.
Treemaps	Uses large rectangles divided into smaller rectangles, with the size representing a quantity.
Node-link diagrams	Also known as network graphs, each node represents an entity.
Tables	Most common chart type, where the rows and columns each represent a different variable.
Gauges	Often used for performance measures, gauges show a single attribute of the data.

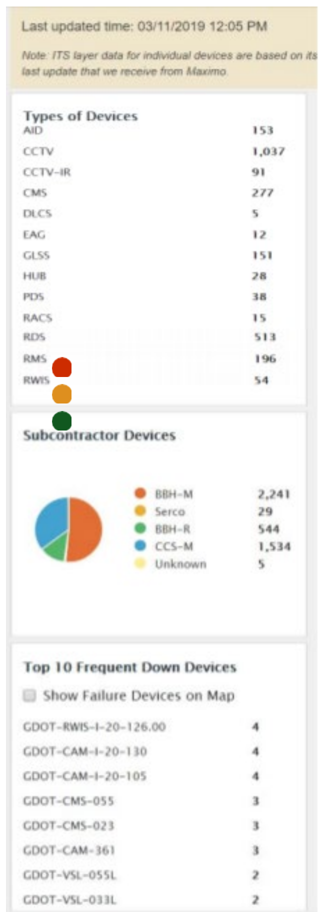
Source: Federal Highway Administration.

Data visualization tools provide analysts with an easy way to create charts to represent data. Charts, Tableau, Grafana, and Excel are a few examples of tools available to help analysts in creating meaningful visualizations. It is important to choose the right type of visualization to provide a clear, concise, and effective message to the end user. Factors for planning data visualizations are listed below:

- **Determine the message to be conveyed** – This helps determine the focus of the visualization and keeps out unnecessary data.
- **Determine the audience** – Information to be presented to management may be different than what will be presented to the general public.
- **Select an appropriate visualization method** – Choose the correct type of chart or graphic to represent the data.

- **Represent the information consistently** – Maintain consistency from chart to chart with items such as icons or color schemes.
- **Keep it simple** – Complex visualizations may confuse the end user. Informed decisions cannot be made with confusing information.
- **Make the information easily accessible** – By placing the information on a website, or any commonly accessible area, the data can be readily retrieved. Once the visualization has been created, it can easily be incorporated into a report or placed on a website for near-real-time dissemination of the information.

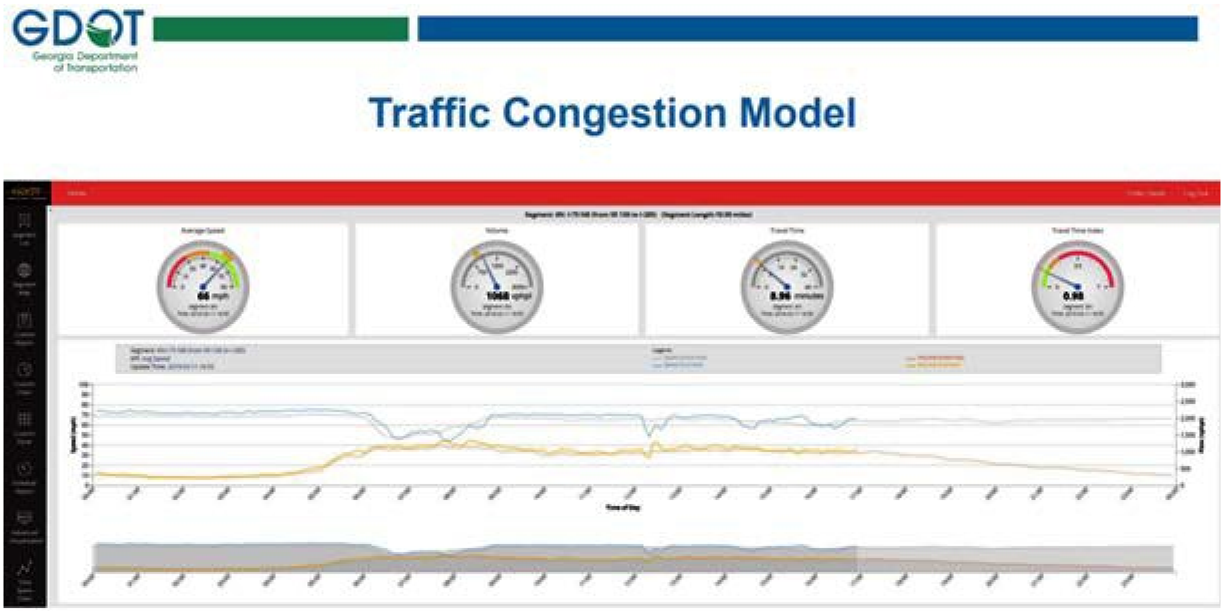
Georgia DOT uses tables as well as pie charts to depict the different types of ITS devices, as well as frequently failed devices (Figure 16).[(19)]



Source: ©Georgia Department of Transportation.

Figure 16. Screenshot. Georgia Department of Transportation current device status.

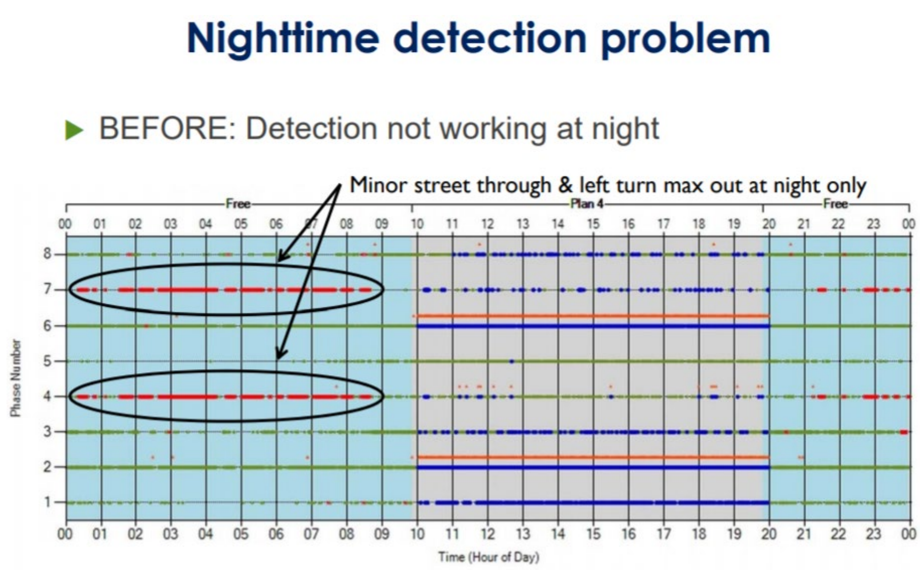
In Figure 17, Georgia DOT uses gauges to depict speed, volume, and travel time information.[19]



Source: ©Georgia Department of Transportation.

Figure 17. Screenshot. Georgia Department of Transportation congestion visualization.

USDOT used data visualization to quickly determine that detection was not working at night (Figure 18).[18]



Source: U.S. Department of Transportation.

Figure 18. Screenshot. U.S. Department of Transportation nighttime detection.

CHAPTER 5. INTELLIGENT TRANSPORTATION SYSTEMS ASSET MANAGEMENT AND OPERATIONS

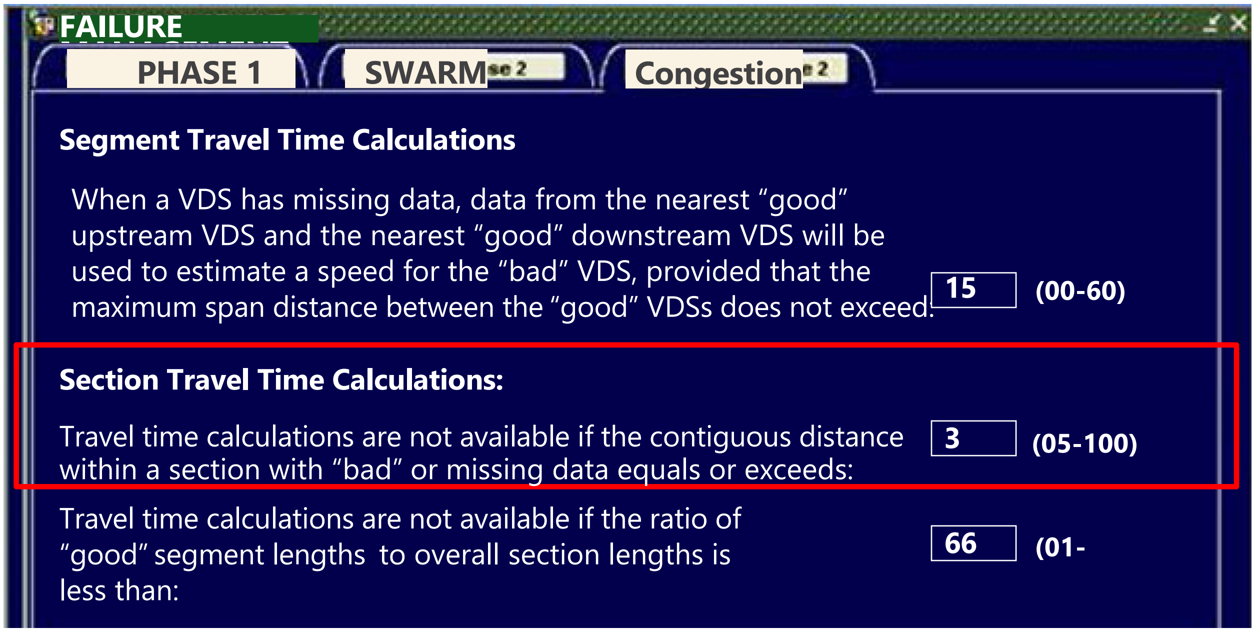
This chapter addresses some key questions on how ITS asset management and operations could be linked to live operations and how to improve operations. As described in previous chapters, the ITS asset management process is an important piece of transportation management and operations. Many of the tools from traditional TAM sometimes are not the best fit for ITS asset management. The following sections describe key questions and answers on how ITS asset management can be linked to transportation operations and how to improve transportation operations.

FAILURES ON INTELLIGENT TRANSPORTATION SYSTEMS DEVICES

Normal ITS devices will not remain active and working indefinitely. Devices such as vehicle detectors, traffic signals, and message signs will have failures, and those failures affect transportation operations. How transportation operations handle and/or recover from failures is critical.

Vehicle Detection Failures

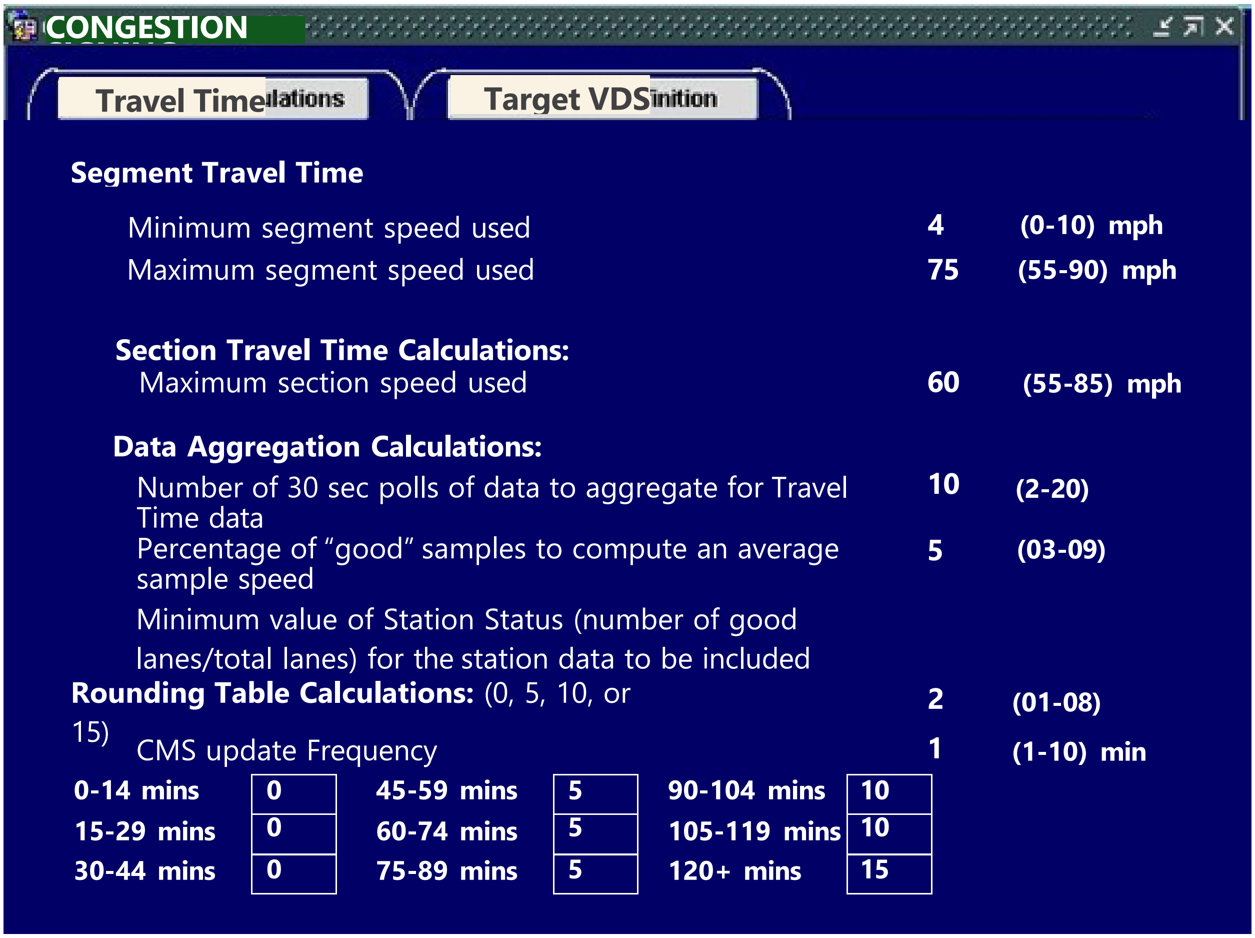
Vehicle detection is crucial for a number of transportation operations. It provides thresholds for event detection, input data for travel time calculations, and inputs into adaptive ramp metering algorithms. What happens if a single vehicle detection station fails? If it is a single failure for 5 miles, then it will likely not be considered a significant gap. However, if multiple detectors failed in a distance of 5 mi, then this could be considered a significant data gap. Certain distances can be set as threshold to allow data to be bridged for different calculations, such as travel times and adaptive metering. As shown in Figure 19, for the California Department of Transportation (Caltrans) District 7 ATMS *Travel Time User's Guide*,[10] the administrator/user is able to define the distance between the detector stations for the calculations. This "bridging" distance allows for some failed vehicle detectors, but when the failures are numerous, the calculations are unable to be completed and the travel time messages are not displayed for the traveling public.



Source: ©California Department of Transportation.

Figure 19. Screenshot. California Department of Transportation District 7 travel times – congestion signing configuration.

Another example, shown in Figure 20, is also from the Caltrans District 7 ATMS *Travel Time User's Guide.*[10] In this example, the data aggregation calculations allow the administrator/user to set the percentage of "good" samples to use in the calculations. Again, if there are too many failures of samples, the calculations are unable to be completed and the travel time messages are not displayed for the traveling public.



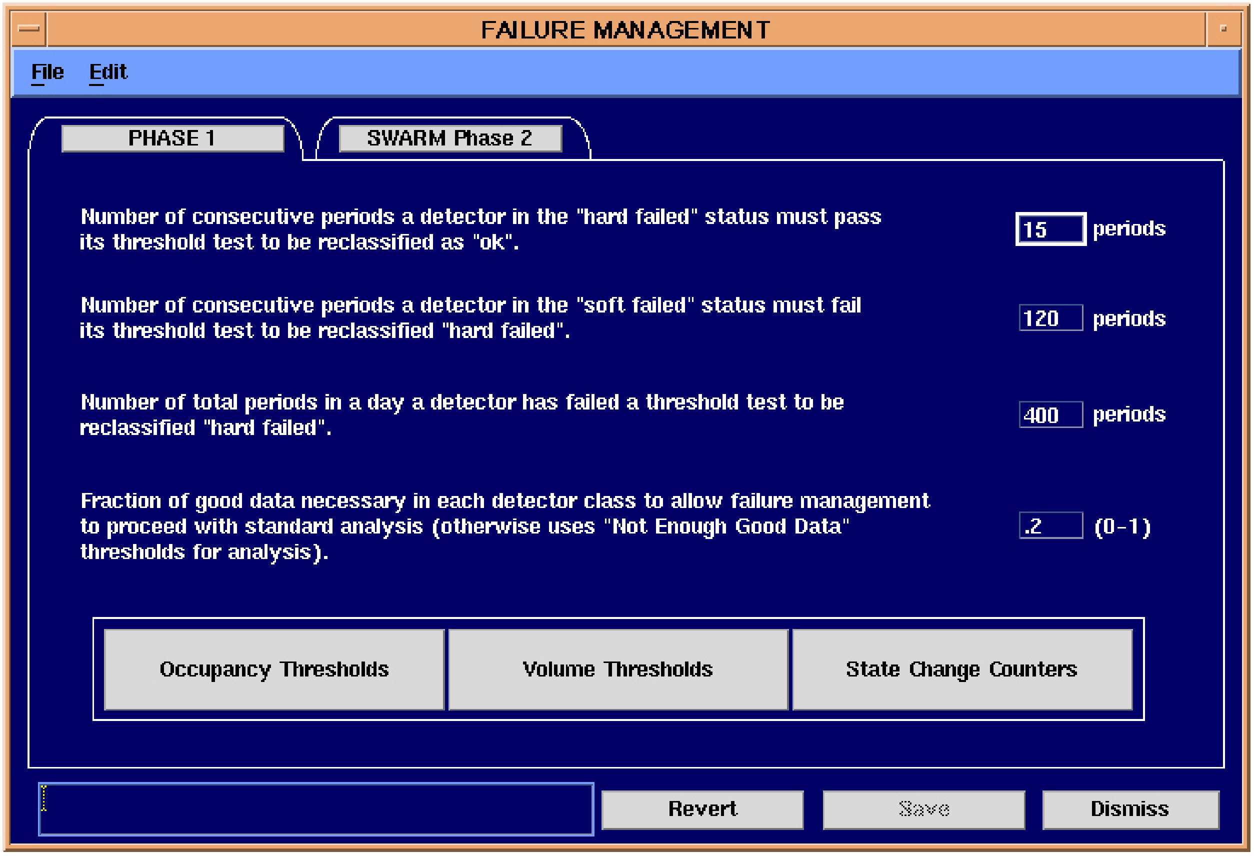
Source: ©California Department of Transportation.

Figure 20. Screenshot. California Department of Transportation District 7 advanced traffic management system – travel time configuration example.

An example of the failure management parameters for the Caltrans District 7 ATMS is shown in Figure 21.[(11)] There are two status for detector information to be included in the calculations—"OK" and "Suspect." The other status are "Soft Failed" and "Hard Failed." As seen in the example in Figure 21, the Caltrans District 7 ATMS thresholds are set as follows:

- Soft Failed threshold to Hard Failed threshold is 60 minutes, or 120 polls consecutively.
- Hard Failed threshold back to "OK" is 7.5 minutes, or 15 polls consecutively.

These thresholds allow the system to be maintained at a high level so that calculations for travel times and other calculations are not impacted.

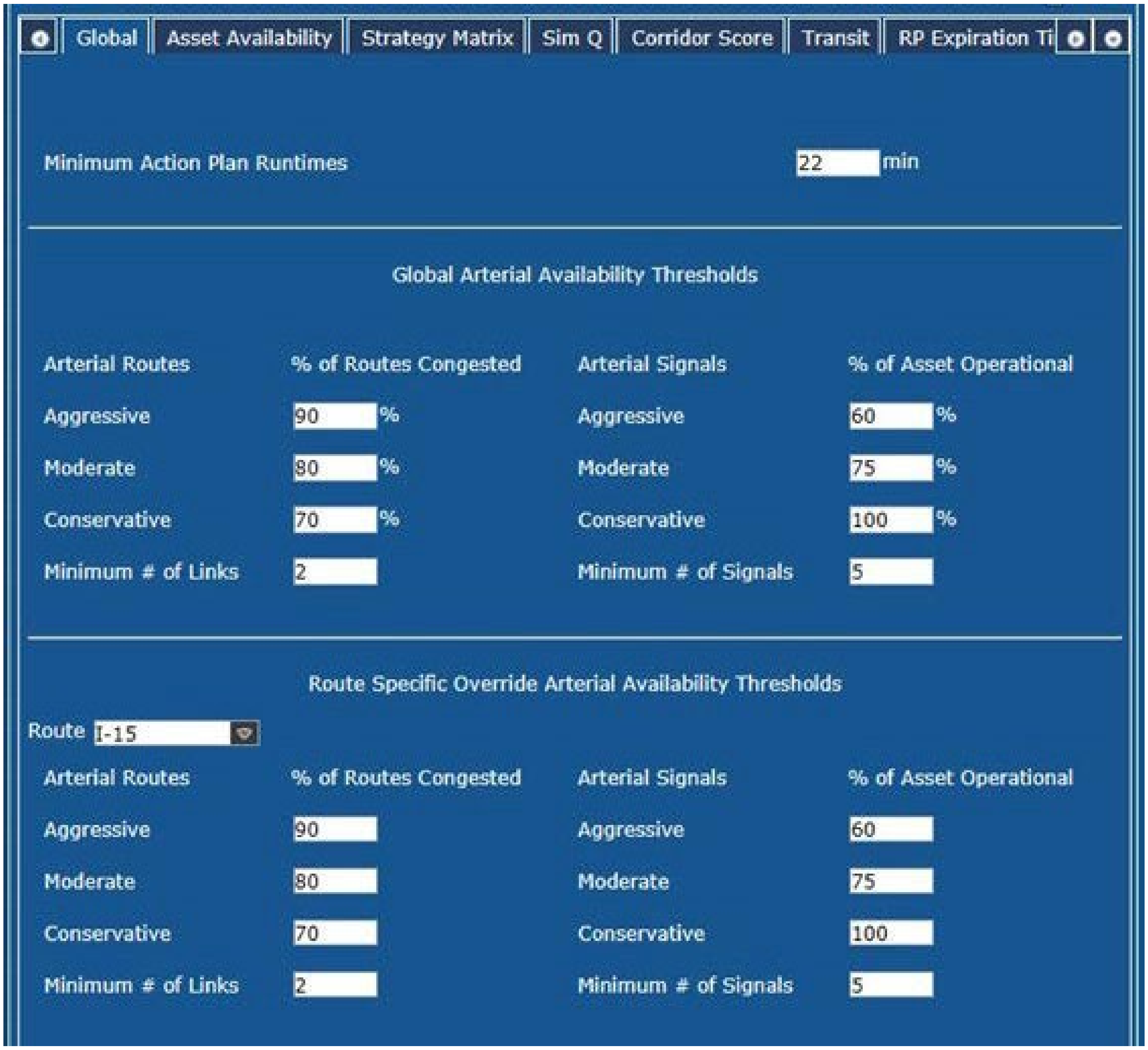


Source: ©California Department of Transportation.

Figure 21. Screenshot. California Department of Transportation District 7 advanced traffic management system – failure management parameters.

Corridor Intelligent Transportation Systems Devices

Corridors often contain a number of ITS devices, such as detection stations, ramp meters, message signs, and traffic signals. Figure 22 is an example of the corridor thresholds for the San Diego Interstate 15 integrated corridor management system.[39] In the example, corridor administrators are able to define the threshold for the number of "operational" signals and ramps, as well as the threshold percentage for the different events' severity. For example, if an event is defined in an "aggressive" state, there must be 60 percent operational signals and there must be a minimum of five signals operational.



Source: ©San Diego Association of Governments.

Figure 22. Screenshot. San Diego Interstate 15 integrated corridor management system – global thresholds.

This type of threshold allows the system to perform and respond to events with a varied operational state. The system can respond effectively despite the failure of a few devices. The decision of the operational thresholds was established at the onset of the system being "live" and has since been discussed and adjusted through the life of the project. Dependent upon agency maintenance efforts, certain devices and/or thresholds are adjusted. For example, if an agency is replacing a communications switch and the associated devices are going to be offline for longer than 24 hours, then the administrator could adjust the devices being evaluated for response plans.

Maintenance of these devices is via system manager monitoring and the San Diego Association of Governments IT Department. If failures do occur, the appropriate agency is notified of the failures. Dependent upon the severity of the failure, time resolving the failure issue could be varied. Recently, a failure occurred that negated the use of an entire diversion route. This failure was a communication (fiber link) cut. The time to resolve was over 3 weeks. While at the same time, a different agency had a signal lose power and go offline. This type of failure was resolved within 24 hours.

Corridor assets can be used in different manners dependent upon the type of event. Figure 23 is an example of the strategy matrix for the San Diego Interstate 15 integrated corridor management system.(41) In this example, a congestion event with a severity of "low" and "yes" for a diversion route is able to recommend routes with signals and 511 messages being used. A congestion event with a severity of "high" and "yes" for a diversion route is able to recommend routes with signals, message signs, ramp meters, and 511 messages. With this ability to customize the response plans, the dependency upon devices being 100 percent operational, 24 hours/7 days a week is alleviated.

Global | Asset Availability | Strategy Matrix | Sim Q | Corridor Score | Transit | RP Expiration Ti

Asset Class Utilization

Event Type	Route Type	Forecasted Impact	Diversion	511	DMS	Arterial Timing	Ramp Metering	Transit	Managed Lanes
Any	Managed Lanes	High	Yes	☐	☐	☐	☐	☐	☐
Congestion	Arterial	Low	No	☑	☐	☐	☐	☐	☐
Congestion	Arterial	Low	Yes	☑	☐	☐	☐	☐	☐
Congestion	Arterial	Medium	No	☑	☐	☐	☐	☐	☐
Congestion	Arterial	Medium	Yes	☑	☐	☐	☐	☐	☐
Congestion	Arterial	High	No	☑	☐	☐	☐	☑	☐
Congestion	Arterial	High	Yes	☑	☐	☐	☐	☑	☐
Congestion	Freeway	Low	No	☑	☐	☐	☐	☐	☐
Congestion	Freeway	Low	Yes	☑	☐	☑	☐	☐	☐
Congestion	Freeway	Medium	No	☑	☐	☑	☐	☑	☐
Congestion	Freeway	Medium	Yes	☑	☐	☑	☑	☑	☐
Congestion	Freeway	High	No	☑	☐	☑	☐	☑	☐
Congestion	Freeway	High	Yes	☑	☑	☑	☑	☑	☐
Congestion	Managed Lanes	Low	No	☑	☐	☐	☐	☐	☐
Congestion	Managed Lanes	Low	Yes	☑	☐	☐	☐	☐	☐
Congestion	Managed Lanes	Medium	No	☑	☐	☐	☐	☑	☐
Congestion	Managed Lanes	Medium	Yes	☑	☐	☐	☐	☑	☐
Congestion	Managed Lanes	High	No	☑	☐	☐	☐	☑	☐
Congestion	Managed Lanes	High	Yes	☑	☐	☐	☐	☑	☐

Save Cancel

Source: ©San Diego Association of Governments.

Figure 23. Screenshot. San Diego Interstate 15 integrated corridor management system – strategy matrix.

Device Failures

As stated above, ITS device failures can result in a number of other failures. A communications failure, whether it is a fiber cut or a communication switch, will result in more than a single failure; multiple devices, such as traffic signals, detector stations, ramp meters, and message signs, could be impacted. Daily health reports and/or maintenance reports can be executed and then failures prioritized for repair.

A number of State agencies all have their own asset tracking mechanism. For example, New Jersey DOT staff generate a daily status report that is sent to their maintenance staff.(33) Similarly, North Dakota DOT staff check the devices each day, and then failure notices are sent to the maintenance staff. South Carolina DOT has their TMC supply a daily camera report to their maintenance staff, which allows the maintenance work order system to prioritize and route service calls and respond to outages statewide to ensure manpower and resources are used to their maximum ability.(9)

CHAPTER 6. IMPLEMENTING PRACTICES

This chapter discusses practices discovered through conversations with State and local agencies and as part of documents reviewed during the literature review.

Several State DOTs voluntarily have included ITS assets as part of the TAMP developed as a requirement of 23 U.S. Code 119 and 23 CFR Part 515. State DOTs whose TAMPs do not include ITS assets could create stand-alone ITS Asset Management Plans that address planning, operating, maintaining, and later replacing devices as they fail. Tasks that could be incorporated as part of ITS asset management planning are listed below.

ESTABLISHING GOALS AND OBJECTIVES FOR PERFORMANCE MEASURES AND ASSET MANAGEMENT

Determining what the desired outcome will be is usually the first step in the process. Goals and objectives can be high level or more defined. Examples of goals include maximizing the reliability, efficiency, and life-cycle costs of the roadway assets and ensuring the effective operation of TMSs. Examples of objectives could be maintaining a greater than 95 percent uptime for all critical ITS devices and 90 percent of ITS devices will operate with 90 percent of their life expectancy.

ESTABLISHING PERFORMANCE MEASURES, TARGETS, AND DATA SOURCES

In everyday life, we measure what is important to us. The process of establishing performance measures confirms this practice of measuring what is important to us. Setting these measures or targets establishes the level of performance aimed for. Examples of common State and local agency performance measures include device uptime and device condition. Once the current performance level is benchmarked, agencies can work to exceed those levels. Data sources must also be identified. Several data sources include TMS software and NMS tools.

ESTABLISHING AN INTELLIGENT TRANSPORTATION SYSTEMS ASSET MANAGEMENT PLAN

The establishment of an ITS Asset Management Plan can take different forms. States can choose to create and implement a stand-alone plan or can incorporate their ITS devices into the State DOT TAMP. Building on the identification of goals, objectives, performance measures, and available data sources as the foundation of an ITS Asset Management Plan, both of these options can provide States with the framework needed to better manage their ITS devices now and in the future.

ESTABLISHING PROCESSES, PROCEDURES, AND STRATEGIES

Several processes, procedures, and strategies to meet State and local agency ITS asset management goals, objectives, and performance measures are listed below.

Inventorying All Assets and the Condition of the Assets in a Centralized Repository

Agencies can create a database that maintains device information, documents device maintenance activities, and maintains a spare parts inventory. Agencies may also want to inventory devices within their TMCs, not just field devices. Devices within TMCs will eventually need to be replaced and can be considered in the process. The system can document ITS field device attributes, such as manufacturer, model, serial number, and date of installation, along with maintenance activities performed on these devices. These data will allow agencies to track maintenance response and repair times and identify recurring device problems.

If one database is not possible, interfaces between databases help facilitate data access. Several databases used by agencies we spoke to also included maintenance trouble ticketing systems making the database more comprehensive and device maintenance efforts more seamless.

Establishing Intelligent Transportation Systems Asset Management Contracts

Many agencies use routine maintenance and emergency repair contracts to maintain their ITS devices at acceptable performance levels. Agencies who choose not to establish maintenance contracts usually have the personnel and in-house expertise to handle these maintenance tasks.

Managing Intelligent Transportation Systems Assets Differently than Other Transportation Assets

Treating ITS assets similar to how pavements and bridges are treated by assessing their condition and value based on age potentially limits capturing data relevant to ITS assets. When ITS assets are managed more like IT, it may be possible to assess their performance, maintenance, and life-cycles more accurately.

Developing an Investment Plan

Once a baseline asset inventory that includes the assessment of the elements condition is completed, an investment plan can be a valuable tool to keep these devices at the conditions needed to maintain the identified performance benchmarks or to get these assets to their desired condition.

Performing Life-Cycle Planning

LCP analysis is an important step in managing ITS devices. LCP analysis considers construction, inspection, maintenance, rehabilitation, and disposal costs at the network level. The goal of an LCP analysis is to find the level of preservation/improvement where life-cycle costs are minimized.

Deploying a Network Management System

Some agencies have installed an NMS to routinely monitor the health of their ITS system. These systems automate the process of checking device health, providing alerts in the case of network outages, and providing dashboards to visualize the data.

Implementing Maintenance Trouble Ticket Systems

Trouble ticket systems report issues such as malfunctioning devices so these repairs can be performed quickly while tracking all information related to the repair. These systems provide an excellent historical resource for device performance and device failures.

Using Operational Data to Improve Transportation Systems Management and Operations Strategies

In addition to using data from ITS devices to monitor the health of the devices, data from ITS devices can be used to improve the application of many TSMO strategies, such as incident management, ramp metering, variable speed limits, variable lane control, and road weather management. As an example, the accuracy of detector data can greatly affect the deployment of strategies such as travel time calculations and ramp metering. If the detectors are not providing accurate data, travel time calculations will not be accurate and the ramp metering system will not effectively manage traffic flows on the roadway facilities.

Coordinating with Other Departments

When developing an ITS Asset Management Plan, from a programmatic level, the importance of coordinating with other departments cannot be overstated. The ITS information is shared with the asset management department if the information will be included in the State DOT's TAMP and with the planning and programming department for assembling future project information. Financial implications will also require coordination with the maintenance department for budget issues and the finance department for cost/benefit analysis of different projects.

INTELLIGENT TRANSPORTATION SYSTEMS ASSET LIFE-CYCLES

Many States struggle with defining ITS asset life-cycles. Is the correct estimation for a CCTV's life-cycle 5 years or is it 10 years? Does an overhead DMS have a 10-year life span or is the life span closer to 20 years? These life-cycle estimates have financial implications, and States will benefit from uniform and consistent life-cycle estimates that allow them to make better-informed financial decisions.

DEVELOPING AN OBSOLESCENCE PLAN THAT ADDRESSES ESTIMATED COST AND TIMELINES FOR REPLACING AGING DEVICES

Once installed, all field devices and devices within TMCs will eventually need to be replaced. Knowledge of the approximate life expectancy of each individual ITS asset will allow agencies to estimate when replacements will be needed for different ITS devices. Anticipating these future replacement expenses allows agencies to develop needs plans and share these with agency decision-makers.

DEVELOPING AN EMERGING TECHNOLOGY PLAN

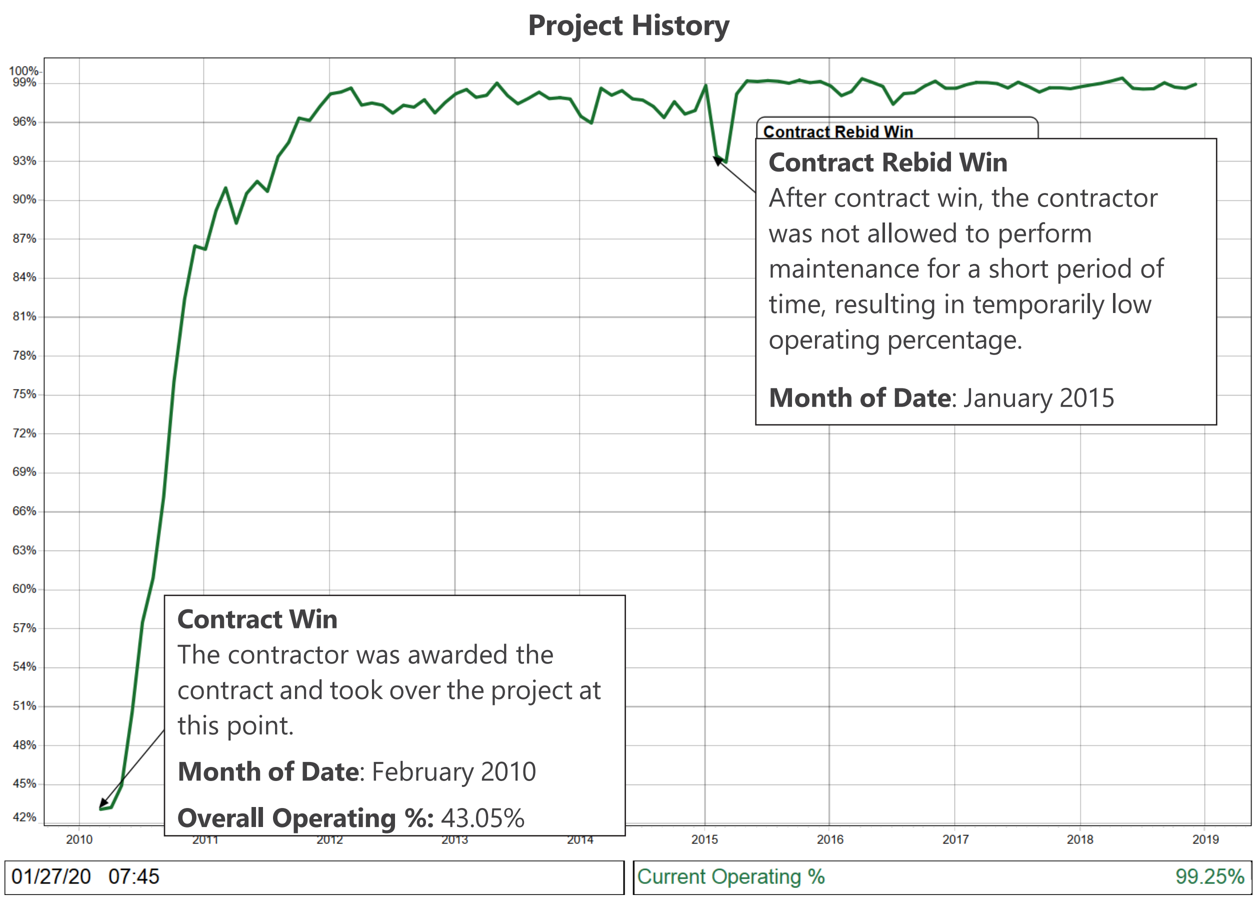
As technology continues to transform the way we live and work, emerging technologies will also transform the way agencies manage their roadways and assets. Examples of emerging technology include the use of crowdsourced data in place of intrusive vehicle detectors and the use of data from connected vehicles in TMCs to provide better situational awareness of the transportation network. Given the rapid changes in the technological landscape, emerging technologies and their applications in TMSs should be considered and planned in advance.

CHAPTER 7. CASE STUDIES

This chapter discusses several case studies of agencies with ITS asset management programs. It includes examples of successful practices. The States of Georgia, Nevada, and Utah are featured. Nevada and Utah DOTs were selected as examples of a smaller system, while Georgia DOT was selected as an example of a larger DOT.

AGENCY A – GEORGIA DEPARTMENT OF TRANSPORTATION

In the last decade, Georgia DOT has created a robust and proactive ITS asset management program. Georgia DOT began their ITS asset management activities in 2009, with each area managing their own assets. This led to differing strategies depending on the type of asset. Over the years, their strategy has improved to include an overarching ITS Asset Management Plan and procedures. Figure 24 shows the improvement in ITS device operations from 2010 to 2019.



Source: ©Georgia Department of Transportation.

Figure 24. Graph. Project history reflecting intelligent transportation systems device operational percentages from 2010 to 2019.

Georgia DOT has developed and submitted a TAMP. The TAMP covers structural assets and roadways; ITS devices are currently not included. The initial TAMP covers the plan for TAM for the entire Department through the year 2027. The plan discusses the Federal TAMP requirements and identifies an asset management road map that contains a clear vision, mission, and goals. The asset management committee, and State DOT-established performance measures with target rates, are described. A description of the asset inventory and evaluation is included, as well as performance targets, life-cycle planning, a financial plan, and investment strategies.

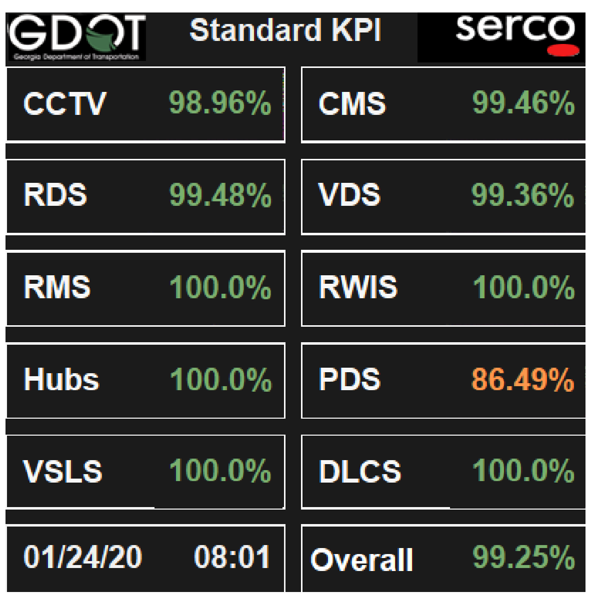
Intelligent Transportation Systems Asset Management Goals and Objectives

Georgia DOT has established several ITS asset management goals and objectives:

- Maintain its current ITS asset network.
- Update and track all changes to the system.
- Maintain highest possible operability of devices within its ITS maintenance assets.
- Upgrade existing assets based on its obsolescence plan.
- Respond quickly to all device issues and downtimes.
- Differentiate devices based on criticality.

Agency Performance Measures and Data Requirements

Georgia DOT currently has an ITS comprehensive maintenance contract that provides an ITS asset management database system. This system is used to track and ticket all devices, update and input devices, and create visualization tools for useful representation of collected ITS data. Figure 25 provides status information about the ITS devices that are monitored. Georgia DOT also has an internal network management software used internally to track network changes and operability of devices. Another tool is used by the comprehensive maintenance contract to manage and track current network outages and device operability as well as maintain HUB connections.



CCTV	98.96%	CMS	99.46%
RDS	99.48%	VDS	99.36%
RMS	100.0%	RWIS	100.0%
Hubs	100.0%	PDS	86.49%
VSLS	100.0%	DLCS	100.0%
01/24/20	08:01	Overall	99.25%

Source: ©Georgia Department of Transportation.

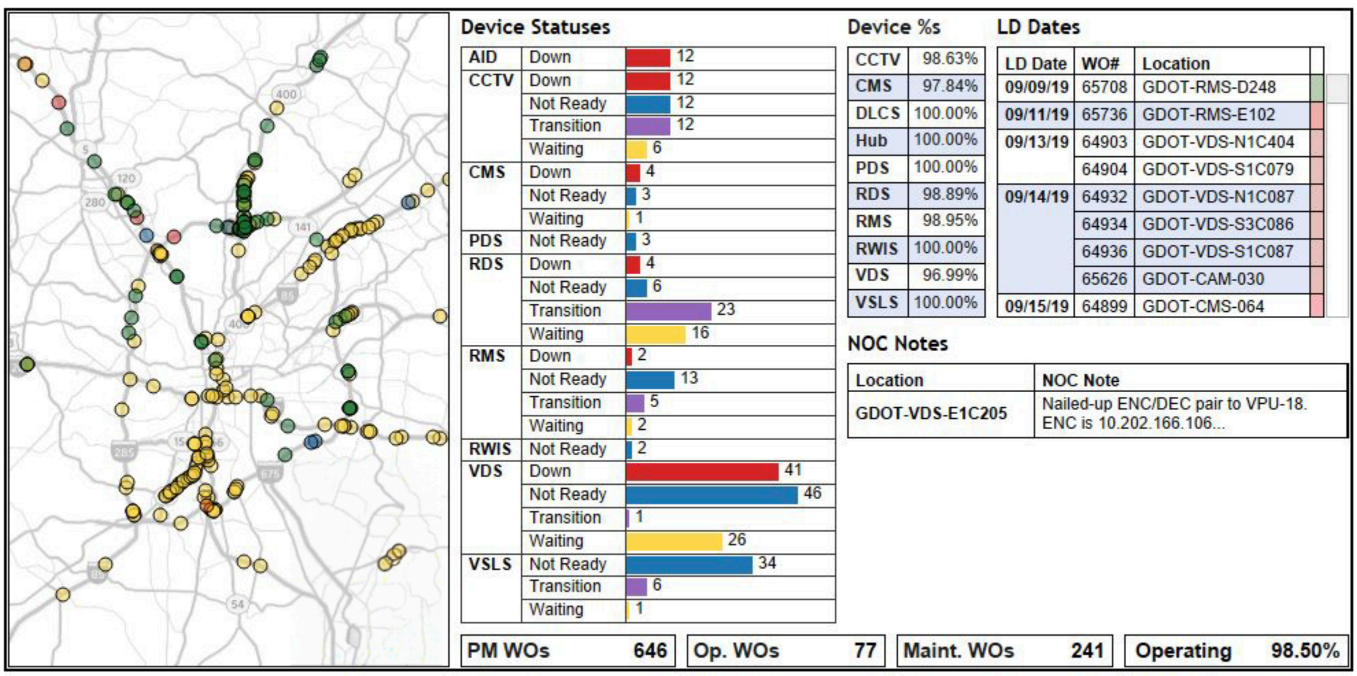
Figure 25. Screenshot. Operational availability status of all intelligent transportation systems devices Statewide.

Device uptime is one of the main performance measures Georgia DOT has selected. Their goal is to have a device uptime of 95 percent at all times. Last year, they averaged approximately a 98- to 99 percent uptime over all devices. One of the areas they have indicated as being important to them, that ties into the 95-percent uptime goal, is the continued uptime of the ITS network and devices during major construction projects. It is extremely important to Georgia DOT to mitigate or reduce issues and risks that would hinder network and device uptime. They have multiple strategies to keep their ITS deployments running during major construction projects, such as the use of aerial fiber and the temporary use of cellular modems.

Similar to several other State DOTs we spoke to, Georgia DOT is also inventorying their fiber network. Data regarding fiber location are critical in maintaining and preserving their system. Several local agencies are also participating in the effort to inventory their fiber assets.

Intelligent Transportation Systems Asset Management Processes

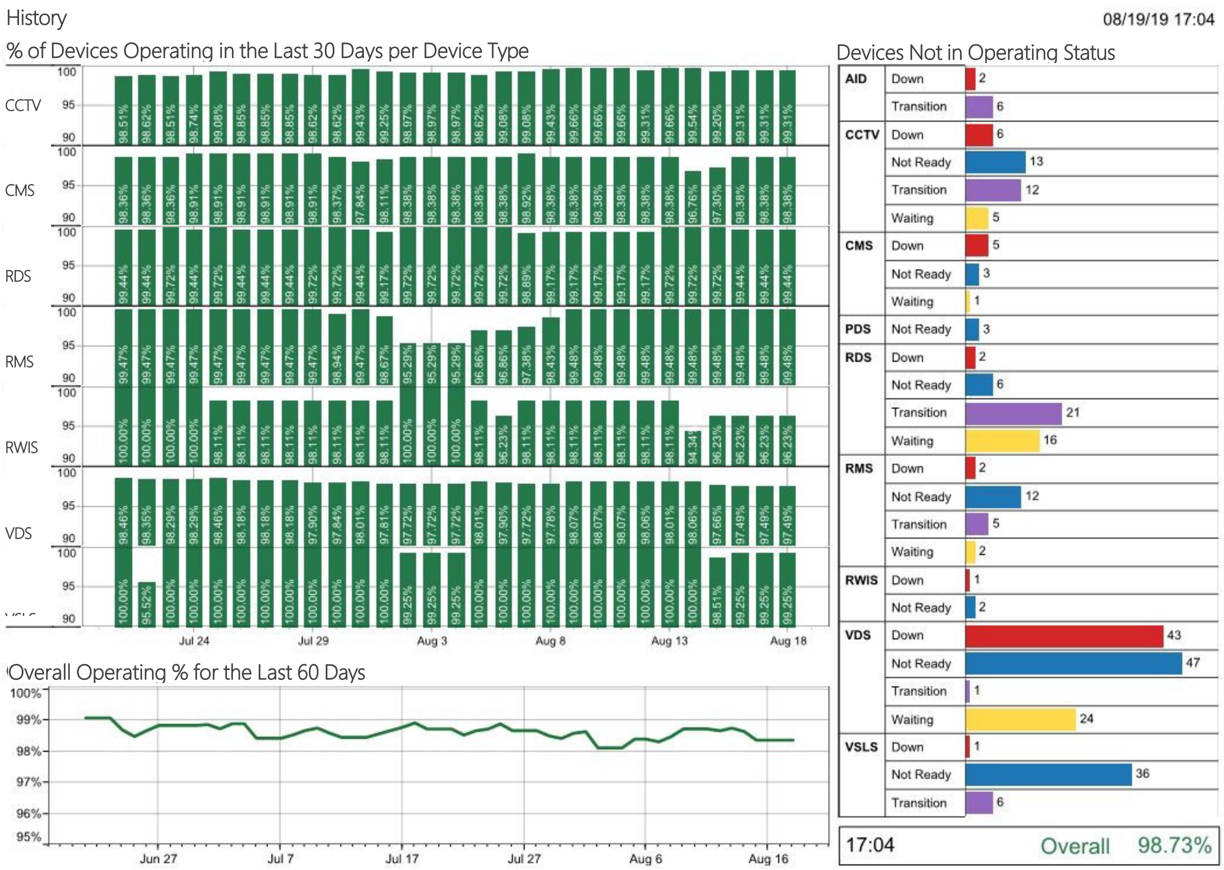
Georgia DOT has several dashboards that provide detailed device information by location, type, and percentages of uptime. These dashboards also show past history of the device status, as well as devices not in operating status. Figure 26 presents a sample dashboard with device information.



Source: ©Georgia Department of Transportation.

Figure 26. Screenshot. Project history reflecting intelligent transportation systems device operational percentages from 2010 to 2019.

Georgia DOT has an ITS maintenance contract under their Office of Traffic Operations that details the specifics for their ITS asset maintenance. The ITS maintenance is performed by an outside contractor, along with subcontractors. A Quality Control (QC)/Quality Assurance (QA) Plan is required to be maintained for this contract, which ensures that the objectives of the contract are met. The contract identifies which devices fall into this contract for routine maintenance, replacement, and repairs. State-selected performance measures include percent uptime for each device type, and payment to the contractor is based on device performance measures. Payment to the contractor can be deducted if a device type fails to meet its goals, and payment is increased if a device type exceeds its goals. Dashboards such as the one in Figure 27 display some of the metrics tracked.



Source: ©Georgia Department of Transportation.

Figure 27. Screenshot. Operational device dashboard – lists the operational status of all devices under Georgia Department of Transportation intelligent transportation systems maintenance.

Georgia DOT has established a Standard Operating Procedures Manual that provides operational guidelines and procedures for the Georgia DOT ITS Maintenance Team. The roles and responsibilities of all team members are clearly defined for both agency and contractor staff. The software tools used are described. The devices can be placed in different operating status, and there are specific procedures and policies governing the changing of a device status. In addition, the format for conducting weekly meetings to discuss ITS maintenance issues is described. Workflows for proper notification and issue resolution are documented as well.

Georgia DOT currently is developing a Connected Data Platform that compiles ITS asset maintenance data, as well as other Georgia DOT data sets, and displays said data into useful dashboards and charts. Device upgrades are useful in replacing older legacy equipment, with lower accuracy thresholds, with more-efficient and more-accurate models. Georgia DOT pilots devices/technologies between different manufacturers, models, and software to test the accuracy of said devices/technologies within a certain window as it pertains to Georgia DOT's goals. NaviGAtor ®(Georgia DOT's advanced traffic management system [ATMS] platform) compiles ITS asset maintenance data and allows for easy viewing of device information, streams/interfaces, and reports using said data. This helps aid in traffic operations and daily ITS maintenance activities. Georgia DOT uses another tool to display segmented traffic data and acquire estimated travel times. This tool uses Georgia DOT's ITS asset management data as its main data source.

Georgia DOT uses Qualifying Products List specifications for devices. This list specifies the metrics and standards that each device must meet. All devices must be approved and on this list to be used. Georgia DOT's ITS specifications are used as a basis for the Qualifying Products List. This is clarified in the ITS comprehensive maintenance contract. Work order information and downtime are also specified in this document.

Current Practices

State DOTs whose TAMPs do not include ITS assets can create stand-alone ITS Asset Management Plans that address planning, operating, maintaining, and later replacing devices as they fail.

Georgia DOT's ITS Asset Management Plan is a checklist of ITS asset management activities agencies can follow, from identifying goals and objectives down to coordinating with other agencies. Also included are steps to discuss these State-selected performance measures, requirements, QA, coordination with other departments, and coordination with other agencies.

In addition to keeping data related to the inventory of ITS devices and the health of these ITS devices, Georgia DOT is also working to improve the quality of the data coming from these devices in an effort to improve TSMO strategies being implemented.

Georgia DOT has implemented variable speed limits, which require accurate detector data. Working with an independent third-party provider, this program produces an automated report that ranks detectors from least accurate to the most accurate. Detectors at the top of the list are the most suspect in terms of their accuracy. An in-house engineer then calibrates the detectors at the top of the list, these being the worst ones from an operational standpoint. The program is evaluating detector availability, and as an example, will flag a detector that is only capturing 40 minutes of data out of the 1 hour instead of the full 60 minutes of data. If the speed measured by a detector is very different from speeds measured by adjacent detectors, then that is another indication of inaccurate detector readings. In both cases, the detectors should be calibrated to improve the data quality that TSMO strategies rely on.

Georgia DOT has also implemented express lanes in Atlanta, Georgia. In advance of the entrances to the express lanes, Georgia DOT posts travel time signs that compare destinations using the regular lanes versus the express lanes, thus allowing motorists to decide which lanes to select. The detector data must also be accurate to run this application.

Georgia DOT has created an obsolescence plan that provides an example of voluntary State step-by-step plans for managing aging ITS infrastructure. Initially, a new technology strategy is defined. Next, a comprehensive set of requirements are developed. Following the requirements, a cost/benefit analysis will be conducted to find the best fit for procuring new technology. Once the technology is installed, employees and technicians must be trained. In the last step, test results are reviewed to evaluate the success and areas for improvement.

Georgia DOT has also instituted the use of QA/QC Plans. Georgia DOT consultants are required at all times to maintain a QC/QA Plan for all work performed under the agreement, including work produced by subconsultants. The ultimate goal is delivery of products that meet or exceed the customer's expectations, as indicated in contract documents.

AGENCY B – NEVADA DEPARTMENT OF TRANSPORTATION

Nevada DOT is one of a handful of State DOTs that include ITS devices in the TAMP. ITS devices included as part of the TAMP are CCTV cameras, DMSs, flow detectors, ramp meters, highway advisory radios, and road weather information systems. ITS devices are discussed in all the major sections of the Nevada DOT TAMP, including asset inventory and condition, performance measures and targets, performance gap analysis, LCP, risk management, financial plan, and investment strategies.

Intelligent Transportation Systems Asset Management Goals and Objectives

ITS assets play an integral role in Nevada transportation as the State's transportation systems become more connected and integrated. Recognizing the importance of ITS and technology, and to use them to their full potential, Nevada DOT has developed ITS asset management strategic elements to help guide health, LCP, risk-based management, and performance monitoring of the ITS assets based on the State's transportation priorities.

Table 14 defines the ITS asset management goals and objectives, as drawn from the ITS asset management vision and mission and in alignment with TSMO strategic goals and objectives.

Table 14. Intelligent transportation systems asset management goals and objectives.

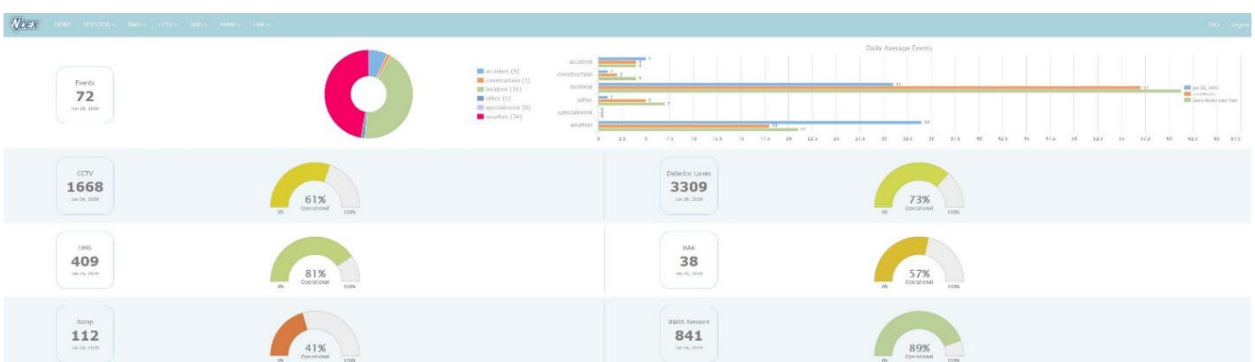
ITS Asset Management Strategic Goals	ITS Asset Management Strategic Objectives
Enable Safer Transportation	Develop crash avoidance, performance measures, and notification mechanisms (e.g., warnings, messages, automated responses, etc.).
Enhance Mobility and Reliability	Increase system efficiency through improved traffic management, work zone and incident management, freight, transit, and road weather management.
Minimize Environmental Impacts	Use technology to manage traffic flow and congestion by efficient use of data to avoid congested routes, to discover available alternate routes, to use public transit, or to reschedule trips.
Enhance Information Sharing	Develop standards, applications, and technologies that enhance information sharing among stakeholders, users, and devices.
Promote Technology and Innovation	Foster innovation and technology advancement and leverage strategic partnerships (public and private) to enable ongoing targeted technology deployment for TSMO integration.
Preserve ITS Assets	Develop specific measures and goals to identify the health status and maintenance requirements for ITS infrastructure and devices.

Source: Nevada Department of Transportation.

ITS = intelligent transportation system, TSMO = transportation systems management and operations.

Agency Performance Measures and Data Requirements

Nevada DOT voluntarily selected device percent operational as one of its performance measures, as seen on dashboards they produce. Several data sources available to Nevada DOT are the Nevada Data Exchange, which is the NDOT ITS data warehouse, the asset management program, the central systems software, proactive traffic management tools, and performance measures data from several different sources. Figure 28 shows a screenshot of a Nevada Data Exchange dashboard.



Source: ©Nevada Department of Transportation.

Figure 28. Screenshot. Example of Nevada Data Exchange dashboard.

Several devices and device information available through Nevada Data Exchange include detector stations, CCTV, DMS, highway advisory radio, environmental sensor stations, and ramp meters. Figure 29 shows a Nevada Data Exchange dashboard for detector communication performance.

Source: ©Nevada Department of Transportation.

Figure 29. Screenshot. Nevada Data Exchange dashboard for detector communication performance.

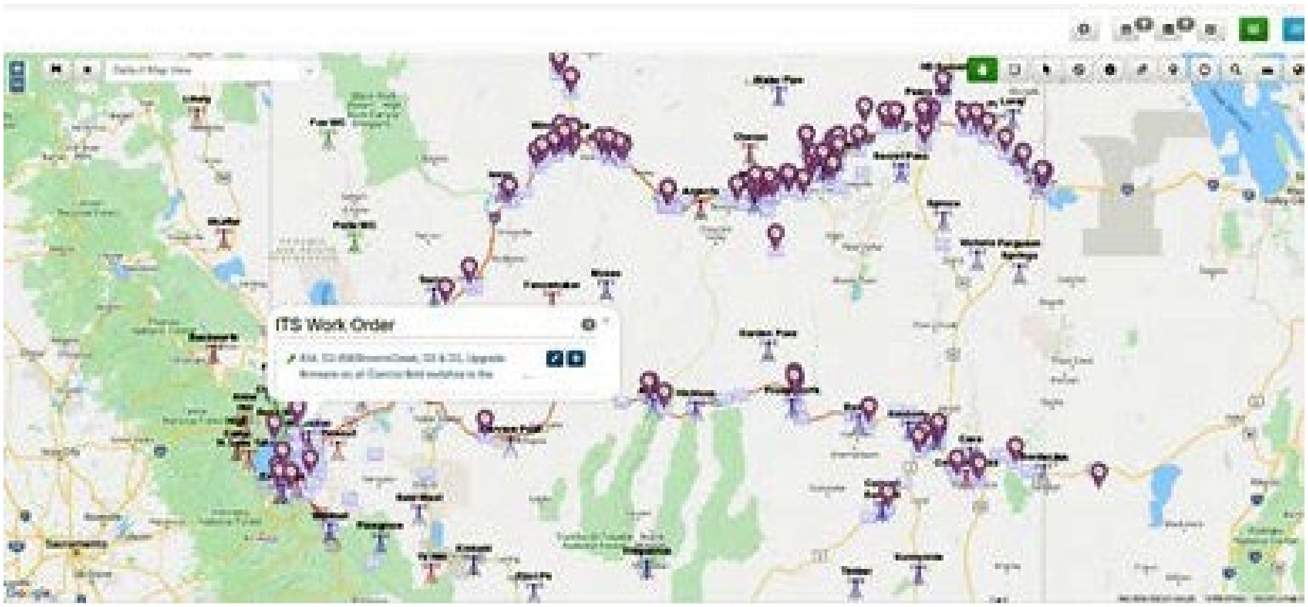
Data sets within TSMO and ITS asset management will help Nevada DOT develop a life-cycle costing framework that will help optimize the transportation system with targeted investments through transparency. It will assist the department for better and more efficient decisions. It will also increase the scalability of the ITS landscape at a technical, business, and organizational level through clear rules for processes and any changes to the processes. Figure 30 shows a Nevada Data Exchange dashboard for DMS communication performance.

Source: ©Nevada Department of Transportation.

Figure 30. Screenshot. Nevada Data Exchange dashboard for dynamic message sign communications performance.

Intelligent Transportation Systems Asset Management Processes

Nevada DOT has a comprehensive ITS maintenance contract. Work order information and downtime allowed are specified in this document. Figure 31 shows the ITS work order map and list produced through asset management processes.



Source: ©Nevada Department of Transportation.

Figure 31. Screenshot. Intelligent transportation systems work order map and list.

Figure 32 shows more detailed work order information provided by asset management processes.

ID	1374
Linked Site	
Request Date	1/23/2020
Reporting Party (Registered)	Connie Hagen
District	D2
Problem Location	SR-431 Incline Village Maintenance Yard
Detailed problem description	Submitted for Mike Fuess, contact Contact Chris Howland, Troy Hammond or Brad Burge for further information if needed. The Incline Village generator was designed to be connected to the ITS network. To our knowledge, this has not happened yet. The hope was that we could access this generator on the network for diagnostics, telemetry, etc. We request a work order t At the maintenance station. It services the TER and the maintenance station. It was installed by HQ TO.
Due Date (Date Time)	**1/23/2020 7:18 AM**
Completed Date	
Work Comment	
Assigned Tech	
Status	Open
Severity	

Documentation 1

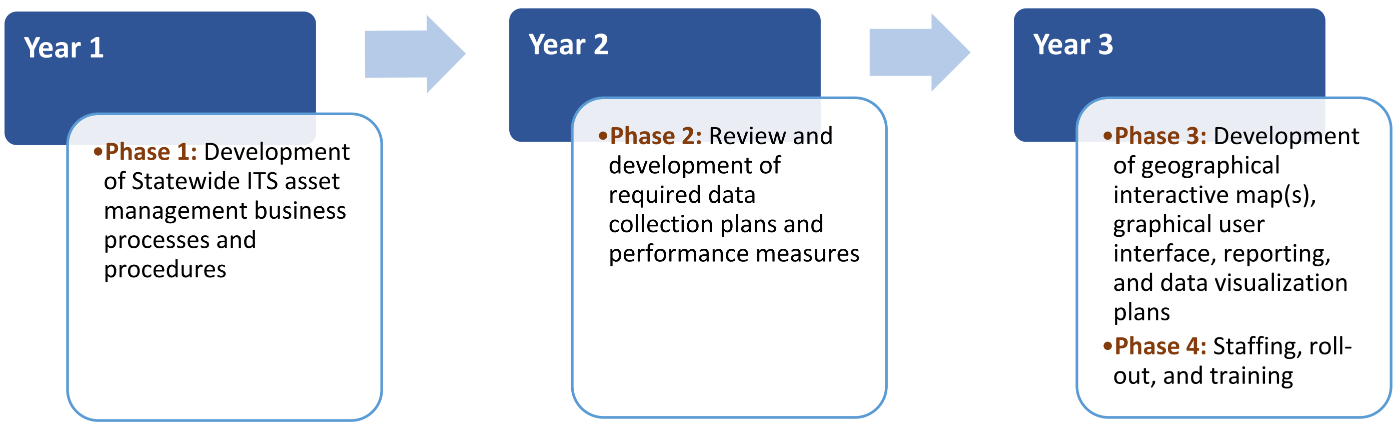
Source: ©Nevada Department of Transportation.

Figure 32. Screenshot. Detailed intelligent transportation systems work order information.

Nevada DOT Recommended Practices

Nevada DOT places great importance on consistency and uniformity of program application and has three districts where each has an ITS maintenance agreement in place. In addition, the department has developed a performance-based agreement with the southern Nevada Regional Transportation Commission Fixing America's Surface Transportation Act partner that aligns with the TAMP.

In early 2020, the Department developed an ITS Asset Management Business Plan describing the step-by-step actions recommended for implementing Nevada DOT's ITS asset management program. The following information is specific to Nevada DOT and serves as an example for other DOT's consideration. Using the literature review, gaps analysis, and Nevada DOT's priorities, the Nevada DOT ITS Asset Management Business Plan recommends a four-phased approach within a 3-year timeframe, as illustrated in Figure 33.



Source: ©Nevada Department of Transportation.

Figure 33. Diagram. Nevada Department of Transportation intelligent transportation systems Asset Management Business Plan four-phased approach.

The following discussion briefly describes the elements within each phase, as suggested in the Nevada DOT ITS Asset Management Business Plan.

Phase 1: Develop Statewide Intelligent Transportation Systems Asset Management Business Processes and Procedures

In alignment with the ITS asset management life-cycle framework and strategic goals and objectives, processes and procedures can be in place to ensure a consistent ITS asset management approach at a statewide level. In addition, this will ensure stakeholders' contribution in data collection and performance measurement and monitoring in a manner that would best support the progress of the State's TSMO strategies and implementation.

Based upon Nevada DOT's current ITS asset management approach and stakeholders' input, the following action items have been developed under three main categories of stakeholder engagement, financial resource management, and QC Plans. Nevada DOT suggests these be integrated into current ITS asset management business processes and procedures.

Stakeholder engagement

Stakeholder engagement plays a key role in developing a consistent Statewide ITS Asset Management Plan. The action items suggested to assist with stakeholder engagement are as follows:

- Provide stakeholders with access to the Asset Management Plan and Nevada Data Exchange.
- Conduct regularly scheduled meetings with stakeholders to coordinate asset management activities (e.g., discuss new local and/or Federal reporting requirements, share information among agencies, discuss performance targets, etc.) and discuss local/regional opportunities and challenges.
- Provide mandatory monthly reporting requirements of the ITS assets status, condition, and health index to stakeholders.
    - Work with stakeholders to develop a list of measures that could be included within the monthly reporting requirements. At a minimum, the report will include ITS measures such as asset's age, deployment year, last scheduled maintenance, next scheduled maintenance, uptime/downtime, life-cycle cost analysis, and number of devices at a high-risk level to determine replacement needs and required resources (e.g., generate automated reports that are available to be viewed on the dashboard and will be automatically archived).
- Establish and adopt a formalized data and performance measures language (e.g., naming convention, data point orders, clear definition/standard for power plants, etc.) to standardize asset management language at a statewide level.
- Host a Data Business Plan Workshop with the Federal Highway Administration (FHWA) for mobility data.
- Assess the possibility of integrating other platforms that include asset management components.
- Coordinate with the Asset Management Oversight Committee.

Financial resource management

Providing a clear understanding of required financial resources for operation and maintenance of ITS assets is critical in sustained performance. More importantly, it will ensure efficient contribution of ITS assets into achieving the TSMO strategic goals and objectives. The Nevada DOT suggested the following action items to enhance their current financial resource management:

- Review and update funding plans:
    - How to allocate funds for ITS maintenance and construction based upon analysis of the impact on achievement of relevant goals and objectives (e.g., allocating a larger budget to identify status of existing assets versus construction of new assets).
- Develop investment strategies, such as an assets prioritization tool and/or operations and maintenance prioritization tool, to assist with the resource and funding allocation decision-making process:

    - Define prioritization criteria and business priorities to use for developing prioritization tools. This element could align with the TAMP ITS network-level life-cycle planning. It has a funding element built-in for annual ITS maintenance for each device type and for a 10-year asset maintenance budget.
- Develop formalized processes for research and deployment of emerging technologies.
- Develop formalized processes for allocation of funds to emerging technologies (at both the testing and deployment phases).
- Review and update the LCP tool and preventative maintenance plans. Currently, the conditions of the ITS assets are based on manufacturer's recommended service life. Good, low risk, medium risk, and high risk are the four conditions used by Nevada DOT to identify ITS assets.
    - To enhance the LCP tool, perhaps Nevada DOT could develop device-specific life-cycle plans. The new life-cycle plans could be integrated into the ITS Asset Management Plan to allow automated reporting based on life-cycle plans for each device.
    - To enhance the maintenance activities for preventative maintenance, perhaps Nevada DOT could develop device-specific definitions for inspection, minor repairs, major repairs, and replacement of ITS devices. This will need to correlate with the TAMP maintenance activity matrix.
- Review and update the risk management analysis tool by defining risk factors and the degree of impact at three different levels—agency, program, and project.
- Develop financial reports and automated replacement cost calculations per device.

Quality control plans

QC Plans for operation and maintenance of ITS assets can be developed, including:

- Reference to any documented standards, manufacturer instructions, local practices, and company procedures.
- Process for adding new devices and associated/required details, such as user manuals, as-builds, specifications, and technical memoranda.
- Process to instigate a change in maintenance of the devices.
- Process for when defective or quality issues are discovered with an asset.
- Standardized process for maintenance hierarchy based on the asset's performance priorities.
- Responsibility matrix, including authority levels, resources, etc.
- Suitable testing, inspection, examination, and audit programs at appropriate stages.
- Performance standards and how performance will be captured.
- Training processes and requirements.
- Testing requirements and specific tools needed.
- Processes of audits and audit frequency.
- Communication to relevant parties of changes to the process and/or safety issues with an asset.

- Schedule of updates for reference documents.
- Development of a dissemination process/framework.

Phase 2: Develop Required Data Collection Plans and Performance Measures

Considering the current data collection plans and the State selected performance measures, the Nevada DOT ITS Asset Management Business Plan suggested this phase include the following:

- Data Collection Plans:
    - Review the data collection mechanism to ensure accuracy of data collection (e.g., KITS, manual data collection, and automated data collection).
    - Map all the capabilities of the ITS Asset Management Plan, Nevada Data Exchange, and incident management sources to determine redundancy within the systems and opportunities for optimization.
    - Review and complete an assets inventory, including identifying missing and redundant assets.
    - Define what "operational" means for each device and align the operational data collection with that definition.
    - Update data collection plans and protocols to include the following:
        - Identification of data gaps to enhance analysis of operation and performance issues.
        - Development of a single maintainable asset data source.
        - Standardized data collection per device and frequency.
        - Technical specifications (time resolution [5 minutes, 30 minutes]).
        - Spatial resolution (1/3 mile, 5 mile).
        - Deficiencies for scheduled repairs or parts.
        - Power (outage, uptime, downtime, and list of power sources).
        - Maintenance (number of work orders, number of troubleshooting events, maintenance checklist, number of emergency repairs, and breakdown classification).
        - Assets utilization.
        - Inspection schedule data.
        - Inspection requirements data.
        - Replacement schedule.
        - Seasonal-based requirements.
        - Location of pedestals.
    - Develop storage and archiving plans.
    - Develop data prioritization tools (in alignment with American Association of State Highway and Transportation Officials data principles).
- Performance Measurement and Analysis:
    - Review and update current ITS performance goals and baselines.

- Create ITS performance measurement reports for the following:
  - Assets utilization.
  - Maintenance frequency per device.
  - Percentage of functionality of assets critical to sustained performance.
  - Maintenance cost per linear mile (aligned with the life-cycle cost per device type and maintenance activity) to maximize integration with the TAMP, ITS Asset Management Plan, and life-cycle cost).
  - Maintenance cost on critical corridors.
  - Operating condition of assets on critical corridors.
  - Budgeted versus actual maintenance cost of the assets.
  - Planned versus actual life-cycle replacement of the assets.
  - Percentage of integrated assets per region.
  - Percentage of uptime/downtime.
  - Percentage of network communication issues.
  - Percentage of successful operation of emerging technology assets at the testing phase.
  - Number of new assets added to the inventory annually.
  - Actual observed assets' life-cycle versus the manufacturer's recommended life-cycle.
  - Failure duration versus rectification duration.

Phase 3: Develop Geographical Interactive Map(s), Graphical User Interface, Reporting, and Data Visualization Plans

Considering the existing capabilities within the Asset Management Plan and Nevada Data Exchange, the Nevada DOT ITS Asset Management Business Plan suggested the following steps to enhance the current system and user experience:

- Integrate available GIS data into one platform (e.g., GIS tool of the ITS Strategic Deployment Plan).
- Integrate troubleshooting, maintenance, and operation strategies (e.g., pop-up notifications with suggested solutions).
- Develop corridor-specific asset maintenance maps.
- Develop corridor-specific ITS strategic deployment maps.
- Define attributes and create a table of attributes per device on the GIS.
- Visualize data on operations and maintenance performance measures through the Nevada Data Exchange, with possible integration of data visualization dashboards (such as Power BI) that can be easily viewed and accessed by stakeholders.
- Develop customizable reporting templates for each stakeholder.
- Issue frequent reports (weekly, monthly, quarterly, etc.) of State-selected performance measures.

Phase 4: Staffing, Roll-out, and Training

For a successful, collaborative ITS Asset Management Plan, it is crucial that stakeholders and staff are provided with sufficient resources. This may require additional staffing with specific skill sets, or educational opportunities for stakeholders. This phase will help Nevada DOT develop a strong basis for future new position requests, as well as staffing and workforce development for the future TSMO Asset Management Plan. This phase will minimally include:

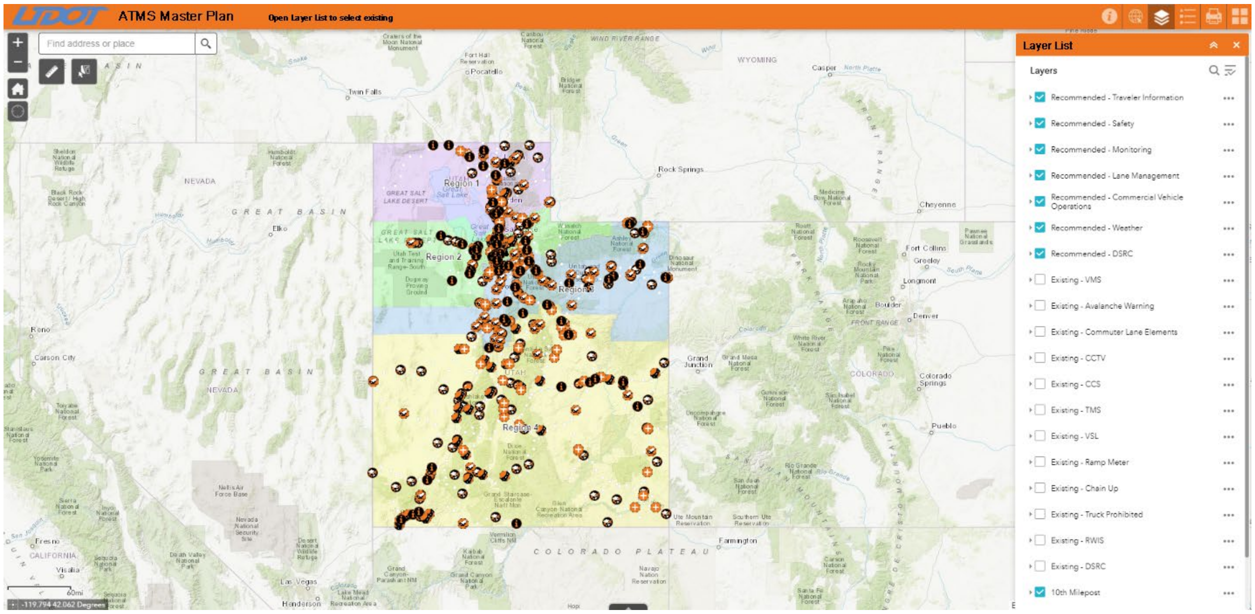
- Identifying staffing needs and skill sets required for operation and maintenance of ITS assets for both the information technology (IT) group and stakeholders, and of emerging technologies.
- Scheduling trainings and workshops for stakeholders to educate them on how to utilize the ITS Asset Management Plan and Nevada Data Exchange.
- Developing recurring meeting plans with stakeholders to address their needs and challenges in utilizing the ITS Asset Management Plan and Nevada Data Exchange.
- Creating the Nevada ITS Asset Management Working Group, which will later transition into the TSMO Asset Management Steering Committee.

AGENCY C – UTAH DEPARTMENT OF TRANSPORTATION

Utah DOT is an example of a State advanced in ITS asset management. It has established three strategic goals—zero fatalities, optimize mobility, and preserve infrastructure. Utah DOT uses the TAMP to achieve its strategic goal of preserving infrastructure. The TAMP provides a roadmap to help guide users with a comprehensive plan for asset management. Some of the key sections within the plan include performance-based management, performance gap identification, LCP, risk management analysis, a financial plan, investment strategies, and some advice on how to continue improving asset management.

Intelligent Transportation Systems Asset Management Goals and Objectives

One of the higher, overarching objectives of the Utah TAMP, which includes ATMS devices and signal systems, is to formalize a data-driven performance-based approach to allocate funds for managing assets such as pavements, bridges, ATMSs, and signal systems. Additional objectives are including asset management into the Department's planning processes and taking risk management into consideration for resource allocation decisions. Figure 34 provides an example of the Utah DOT ATMS Master Plan.



Source: ©Utah Department of Transportation.

Figure 34. Screenshot. Utah Department of Transportation Advanced Traffic Management System Master Plan.

Agency Performance Measures and Data Requirements

Utah DOT chose to establish performance measures and targets for both their ATMS devices and their signal systems. The devices described in the TAMP fall within three different tiers. ATMS devices (e.g., CCTV cameras, variable message signs, ramp meters, communications network, road weather information system, highway advisory radios, etc.), as well as signal devices, are part of Tier 1 in addition to pavement and bridge assets.

The ATMS system is comprised of several different types of devices. The measure and target are tracked separately and reported monthly for each type of device and averaged into a composite score. The target is 95 percent of devices in operation.

Utah DOT tracks the health of traffic signal systems through ongoing preventative maintenance and performance monitoring. The State-established performance measure for the Utah DOT signal system is the percent of signals that are in good or fair condition based on annual inspection of all electronics and physical infrastructure associated with signal systems. This information is provided monthly by the Utah DOT Traffic Management Division. The signal condition target is 95 percent of signals in average condition or above. Both are currently below their established target levels, although there are plans and funding in place to reach the established targets over the next few years.

Intelligent Transportation Systems Asset Management Processes

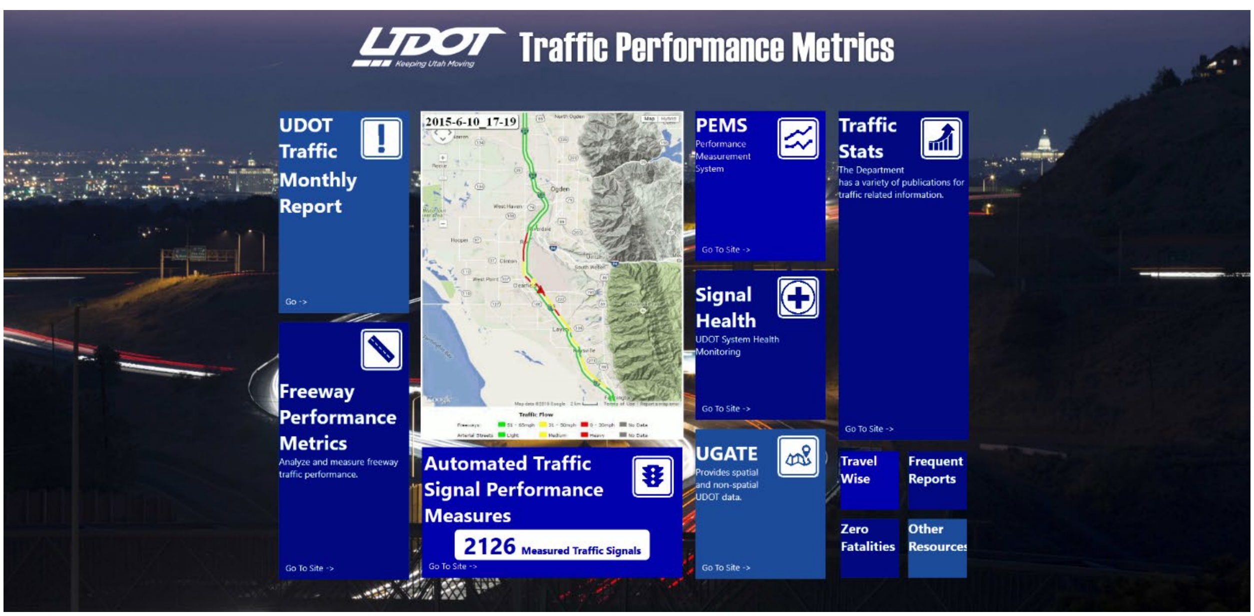
Utah DOT uses a web-based asset inventory and work order system to account for and manage its system. The application contains a work order management system; inventory control management system; staff management system; work group management system; other sections for configuring privileges and locations; and an administration management system for managing component types, failure types, projects, manufacturers, and vendors.

Utah DOT has developed LCP for ATMS devices and is in the process of developing life-cycle plans for signal systems. Utah DOT replaces ATMS devices prior to the end of their useful life before failure. Signal systems are replaced on a priority basis depending on funding available at the time.

Current Practices

Utah DOT has established a dashboard that displays several optional ITS asset performance measures and targets. The dashboard can be found at http://www.udot.utah.gov/strategic-direction/preserve-infrastructure.html.

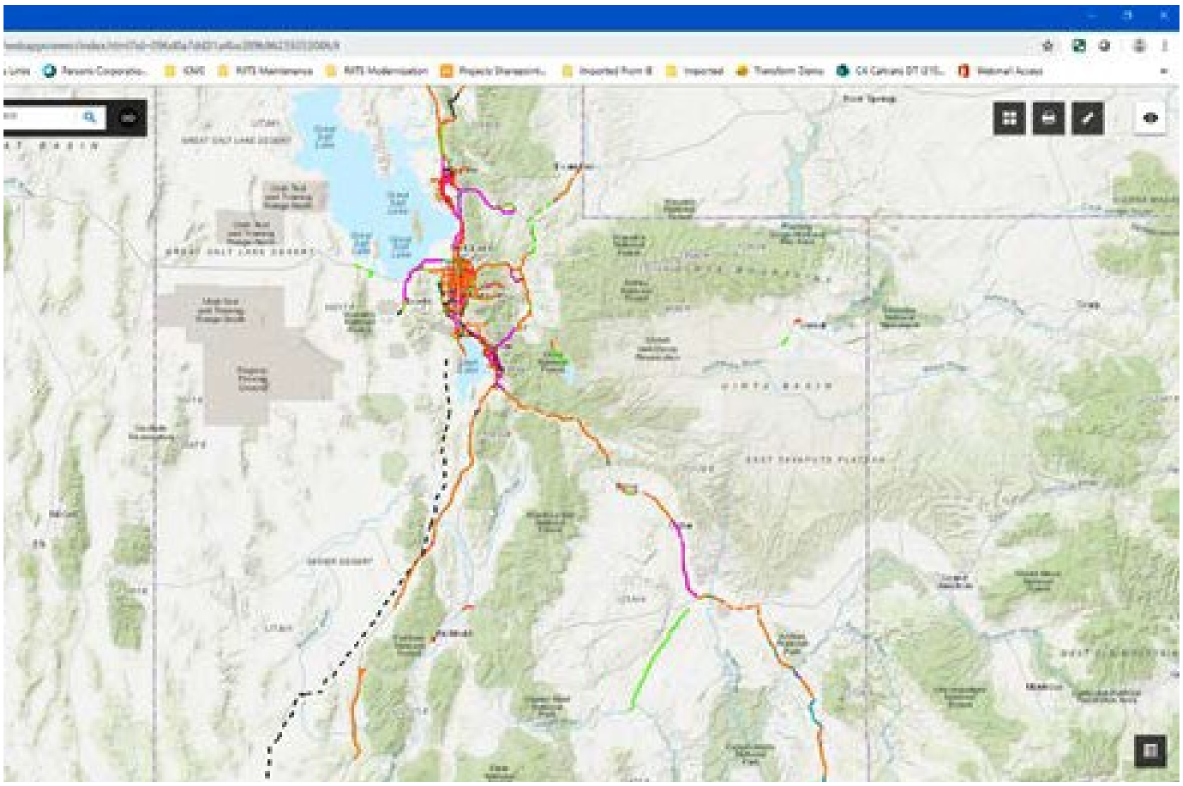
Utah DOT has also developed a website titled Traffic Performance Metrics (located at http://www.udottraffic.utah.gov/performancemetrics/default.aspx) that provides users with links to several different reports and measurements relating to traffic (e.g., traffic monthly report, freeway performance metrics, performance measurement system, system health monitoring, spatial/non-spatial data, and traffic statistics), as shown in Figure 35. Each of these links provides users with data that may be viewed, downloaded, or have a type of interaction on a map.



Source: ©Utah Department of Transportation.

Figure 35. Screenshot. Utah Department of Transportation Traffic Performance Metrics webpage.

Utah DOT maps out its existing fiber optic network and ATMS infrastructure and provides that information on a website (Figure 36). Useful for future network expansions and relocations, the data displayed on the map include conduits, cables, junction boxes, cabinets, and other communications networks tied to Utah DOT. This website can be accessed at https://horrocks.maps.arcgis.com/apps/webappviewer/indexhtml?id=096d0a7dd31a4be289b9623935308fc9.



Source: ©Utah Department of Transportation.

Figure 36. Screenshot. Utah Department of Transportation fiber map.

Utah DOT also produces a Traffic Management Division Monthly Report that provides valuable information about field devices and summarizes operations during the month. Graphs depicting the percentage of device availability for CCTV, vehicle message signs, ramp meters, signals, and road weather information systems are also included. Device work order information, such as number of new work orders, new work orders by device types, and average work order turnaround days, is presented graphically.

APPENDIX A. EXAMPLES OF ITS PERFORMANCE MEASURE REPORTS AND DASHBOARDS

This appendix includes examples of ITS performance measure reports and dashboards currently used by different agencies to represent how different agencies measure and provide reporting related to ITS asset management (see Figure 37 through Figure 42).

TSAMS | **TSAM008 - ITS Device Uptime % By District** | PDIF

Report Dates: Start: 7/1/2019 End: 7/31/2019

Run Date : 8/27/2019
Run Time : 8:31:35AM

Statewide				
	Total Device Hours	Total Downtime(hrs)	Uptime % Target	Uptime %
CCTV	742,800	18,112	97.4%	97.6%
Permanent DMS	365,760	7,851	97.3%	97.9%
Semi - Permanent DMS	49,680	973	97.1%	98.0%
HAR	85,680	2,781	97.0%	96.8%
All Devices	836,400	29,716	97.1%	96.4%

Southeastern Region				
District 6				
	Total Device Hours	Total Downtime(hrs)	Uptime % Target	Uptime %
CCTV	316,800	10,800	98.0%	96.6%
Permanent DMS	123,840	3,600	98.0%	97.1%
Semi - Permanent DMS	5,760	0	98.0%	100.0%
HAR	0	0	0.0%	0.0%
All Devices	446,400	14,400	98.0%	96.8%

Source: ©Pennsylvania Department of Transportation.

Figure 37. Screenshot. Example of traffic signal asset management systems report.

Traffic Operations - Daily Readiness Log

DAILY STATISTICS REPORT

Daily Log Number: 2161

Date of Inspection: 8/9/2019 12:10:00 AM

Regions: North and South

Inspections Began at: 8/9/2019 12:18:00 AM

Inspections Ended at: 8/9/2019 4:45:00 AM - Duration (267) minutes

KPTs

OVERALL

Percent Functional (North): 92.075 % Percent Functional (South): 87.955 % Percent Functional (N&S): 90.428 % **NJDOT OWNED**

NJDOT Percent Functional (North): 91.553 % NJDOT Percent Functional (South): 86.986 % NJDOT Percent Functional (N&S): 89.726 % **NON-NJDOT OWNED**

NON-NJDOT Percent Functional (North): 92.063 % NON-NJDOT Percent Functional (South): 93.878 % NON-NJDOT Percent Functional (N&S): 92.857 %

General Counts

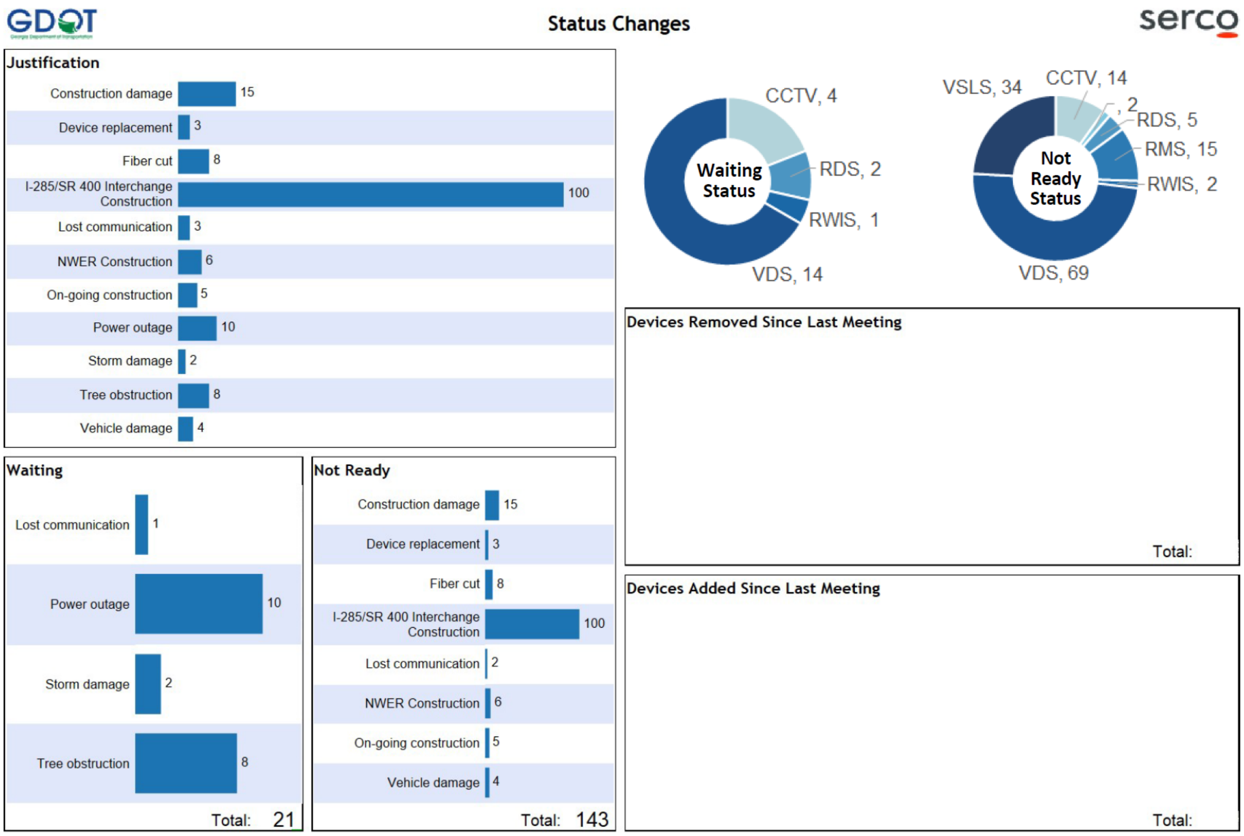
Total Number of Devices: 888

Total Number Inspected: 773

Work Orders Generated by this inspection process (North): 4

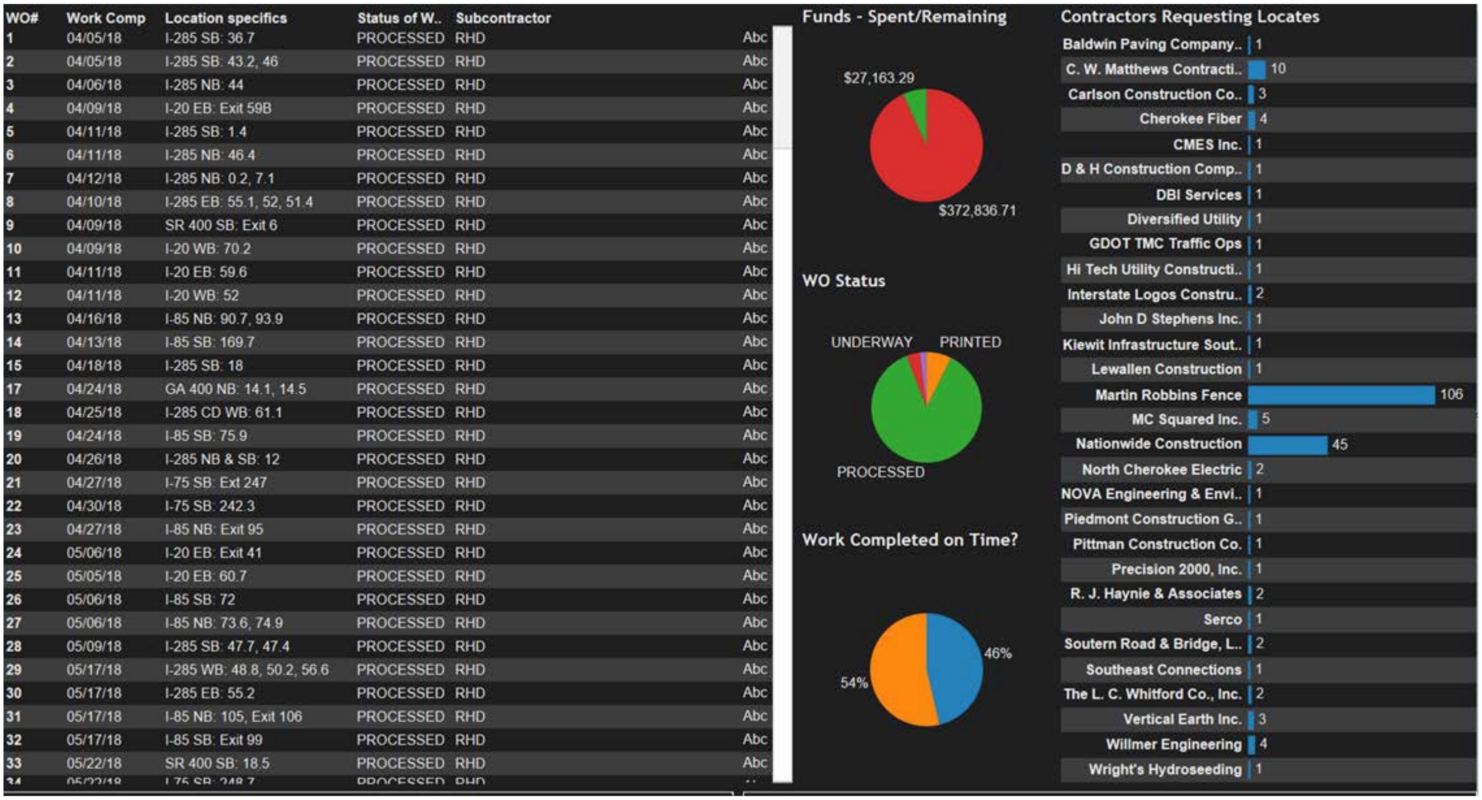
Source: ©New Jersey Department of Transportation.

Figure 38. Screenshot. Example of daily report generated after device inspections.



Source: ©Georgia Department of Transportation.

Figure 39. Screenshot. List of devices that are inoperable due to third-party/construction damage.



Source: ©Georgia Department of Transportation.

Figure 40. Screenshot. Dashboard of fiber locates approved by Georgia Department of Transportation intelligent transportation system maintenance.

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