Preliminary Investigation (PI-0234)

Caltrans Division of Research, Innovation and System Information

Statewide Asset Data Collection and Management: Survey of Practice

Requested by
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Table of Contents

Executive Summary **2**
- Background 2
- Summary of Findings 2
- Gaps in Findings 7
- Next Steps 7

Detailed Findings **8**
- Background 8
- Survey of Practice 8
- Related Research and Resources 36

Contacts **47**

Appendix A: Survey Questions **49**

Executive Summary

Background

The California Department of Transportation (Caltrans) is investigating the use of a unified and coordinated statewide approach to transportation asset management. This practice takes a project-specific and programmatic approach to collecting and managing agency asset data, and Caltrans would like to capitalize on the efficiencies gained through a "collect data once, use it many times" strategy. Collection efforts may employ a range of tools, including Global Positioning System (GPS) devices, multisensor mobile mapping platforms, airborne and terrestrial LiDAR, surface geophysics, unmanned aerial systems and photogrammetric processes.

Caltrans is seeking information from other state transportation agencies about current and best practices for using a coordinated statewide approach to data collection and management, and lessons learned as these agencies collect, extract and manage transportation asset and roadway characteristics data**.** Experiences and knowledge from agencies with mature programs that collect and manage enterprise asset data are expected to inform the development of a Caltrans strategic statewide plan that will address the programmatic collection and management of field-collected roadway and roadside assets.

To assist Caltrans in this information-gathering effort, CTC & Associates conducted an online survey of state transportation agencies or other agencies expected to have experience with data collection and management. A literature search of publicly available resources about national and state practices and guidance supplemented the survey findings.

Summary of Findings

Survey of Practice

An online survey was distributed to members of two American Association of State Highway and Transportation Officials (AASHTO) committees:

- Subcommittee on Asset Management.
- Committee on Performance-Based Management.

In addition, the survey was distributed to a representative of the North Carolina Department of Public Safety (North Carolina DPS) who was expected to have experience with a coordinated statewide approach to asset data collection and management.

Representatives from 13 state departments of transportation (DOTs) and the North Carolina DPS responded to the survey. Twelve agencies have established a coordinated statewide approach to collecting and managing data on a range of agency assets. Two state DOTs have not established a coordinated statewide approach to multiasset data collection and management but are considering establishing a new program or expanding their current practices to allow for a coordinated statewide approach.

Findings from the 11 state transportation agencies and North Carolina DPS are presented in the following topic areas when provided:

- Program description.

- Asset data collection.
- Asset data management.
- Assessment of agency practices.

Program Description

Program Implementation

Use of a coordinated statewide approach varied considerably among these agencies, and with Kansas and Minnesota DOTs, varied by asset class. More than half of these agencies have used this approach for more than 10 years:

- 0 to 10 years: Alabama, Hawaii, Minnesota, New Hampshire, New York and Utah.
- 10+ years: Minnesota and Virginia.
- 20+ years: Delaware, Kansas, Minnesota and North Carolina DPS.
- Approximately 30 years: Kansas and Mississippi.
- 40+ years: Iowa.

Staffing

Three-quarters of the agencies use both consultants and in-house staff to collect, store and analyze data, depending on the task and the asset (Alabama, Delaware, Minnesota, Mississippi, New Hampshire, New York, North Carolina and Virginia). Three states use consultants only (Hawaii, Iowa and Utah), and one state uses in-house staff only (Kansas).

Frequency of Data Coordination and Collection

Half of the agencies coordinate and collect data annually (Hawaii, Iowa, Kansas, New York, Utah and Virginia). The remaining six agencies collect data in varying cycles (Alabama, Delaware, Minnesota, Mississippi, New Hampshire and North Carolina DPS). In Minnesota, coordination occurs continuously and varies by priority and effect on asset data quality. The respondent noted that the agency philosophy is to “collect data once and maintain its currency on an ongoing basis in real time.” The North Carolina DPS respondent said that imagery is collected one quarter of each year, and LiDAR is collected approximately every 10 years or as needed. None of the agencies responding to the survey collect data every two years or every three years, although Alabama DOT is aiming for a three-year cycle.

Type of Roadways

The three most common types of roadways where asset data is collected are state roads (Alabama, Hawaii, Kansas, Minnesota, Mississippi, New York, Utah and Virginia), all public roads (Iowa, New Hampshire, North Carolina DPS and Virginia), and ramps and connectors (Hawaii, Minnesota, New Hampshire and Virginia). Hawaii DOT collects data from county collector roads and above; Mississippi DOT gathers data on all state-maintained routes plus various routes on functionally classified roads for Highway Performance Monitoring System (HPMS) reporting.

Published Standards or Procedures

Eight agencies have adopted or published standards or procedures for collecting and managing asset data from their enterprise statewide programs (Iowa, Kansas, Minnesota, Mississippi, New Hampshire, North Carolina DPS, Utah and Virginia). In Minnesota, Mississippi and New

Hampshire, these procedures are currently available internally as agencies work to create or standardize them.

Three respondents shared agency resources, including data dictionaries (Hawaii and Iowa) and district and state maps illustrating aspects of pavement performance (Kansas). Other resources cited were the Federal Highway Administration (FHWA) Highway Performance Monitoring System Field Manual (Mississippi) and issue papers that describe LiDAR data collection practices for land mapping (North Carolina).

Asset Data Collection

Core Set of Assets

Eleven agencies collect data for bridges and pavement. Other assets that are commonly monitored are barriers (Alabama, Hawaii, Iowa, Minnesota, New Hampshire, New York, Utah and Virginia); drainage features (Hawaii, Iowa, Kansas, Minnesota, New Hampshire, New York, Utah and Virginia); and signs (Alabama, Hawaii, Iowa, Minnesota, New Hampshire, New York and Utah). None of the 11 agencies collect data on loop detectors. Agencies are least likely to collect data on cabinets, lands and buildings, marking or sign reflectivity, ramp meters, rights of way and roadside facilities.

Data Collection and Extraction Methods

Ten agencies use GPS devices in asset data collection and extraction (Alabama, Hawaii, Iowa, Kansas, Minnesota, Mississippi, New Hampshire, North Carolina DPS, Utah and Virginia). Other commonly used technology and tools are terrestrial LiDAR (Alabama, Hawaii, Iowa, Kansas, Minnesota, Mississippi, North Carolina DPS and Utah); manual data collection (Iowa, Kansas, Minnesota, Mississippi, New Hampshire, North Carolina DPS, Utah and Virginia); and mobile devices (Alabama, Iowa, Minnesota, Mississippi, New Hampshire, Utah and Virginia). Tools and technology least used are airborne LiDAR, photogrammetric processes and surface geophysics.

Utah DOT is currently experimenting with the use of unmanned aerial systems (UAS) for data collection and extraction. In addition to other methods, Hawaii DOT is using the laser crack measurement system (LCMS) to collect pavement condition data.

Data Collection and Coordination Practices

In 10 of 11 agencies, both in-house staff and contractors perform the field asset data collection, extraction and management, depending on the asset. New York State DOT uses contractors only for these functions. None of the participating agencies use in-house staff only.

Agencies in six states (Iowa, Kansas, Minnesota, New Hampshire, New York and Virginia) collect asset data in all stages of project delivery, from design through construction. This data is then entered into asset management information systems for future use.

To avoid duplication and still meet the competing demands for the type and extent of asset data, agencies primarily coordinate efforts with other functional areas. In Alabama, Minnesota and New Hampshire, specific business units within each agency coordinate data collection. Utah and Virginia DOTs distribute responsibility among multiple divisions and champions. Hawaii DOT has developed a data dictionary and tools that are used throughout the agency by functional units such as maintenance, design and safety. The Mississippi DOT's Planning and Research divisions use the same contract for HPMS and PMS data collection and extraction,

while North Carolina DPS coordinates large-scale data collection with the North Carolina Geographic Information Coordinating Council.

Data Quality Management Plan

Nine agencies have a data quality management plan for data collection. Four DOTs (Kansas, Mississippi, Utah and Virginia) have a plan that can be shared. (See Data Quality Management Plan in **Detailed Findings** for resources from Kansas, Mississippi and Utah.)

Five agencies (Iowa, Minnesota, New Hampshire and New York State DOTs and North Carolina DPS) have a plan but can't share it because the plan is under development, is not a formal written document or varies by asset. Several respondents provided agency resources related to data collection and quality management resources, including 3D technologies and data collection vehicles (Hawaii) and the use of LiDAR for highway inventory data collection (Utah).

Asset Data Management

Staff Access to Data

Data products. Respondents from 11 agencies described the products from the data collection and extraction efforts that are made available to staff, including extracted assets, imagery and point cloud data. All agencies make extracted assets available to staff, and all except Minnesota DOT make imagery available. The Minnesota DOT respondent noted that imagery and point cloud data are available to staff by special request. Point cloud data is available to staff in seven states: Alabama, Hawaii, Iowa, Mississippi, North Carolina, Utah and Virginia. Other products provided to staff are pavement management system data (Mississippi) and GIS data (New Hampshire).

Data distribution. Agency-hosted web-based applications are used by nine agencies to share asset data with staff (Hawaii, Iowa, Kansas, Minnesota, Mississippi, New Hampshire, New York, Utah and Virginia), and eight agencies use enterprise data warehouses (Hawaii, Iowa, Minnesota, Mississippi, New Hampshire, New York, Utah and Virginia). Only two state DOTs use consultant-hosted web applications (Hawaii and Iowa) or multiple data marts (Hawaii and Virginia). Less frequently used methods are separate databases (Hawaii, Minnesota, Mississippi, New Hampshire and Virginia); web services (Hawaii, Iowa, Minnesota, New York and Virginia); and separate geodatabases (Hawaii, Minnesota, New Hampshire and Virginia).

Asset Data Migration and Storage

Survey respondents reported three primary practices for asset data migration and storage: web services (Alabama, Iowa, Kansas (pavement data), Minnesota and New Hampshire), contractors (Hawaii), and mobile and paper processes (Kansas (bridge data)). Utah DOT is currently procuring a new maintenance/asset management system for data migration and storage.

Asset Data Delivery Format

To deliver asset data, five agencies use a standard format that is open to a third party, allowing full access to the data (Iowa, Kansas, New York and Utah DOTs and North Carolina DPS). The North Carolina DPS respondent added that agency data is available via a web site and is provided to North Carolina DOT. Only Alabama DOT uses a vendor proprietary format with a perpetual license provided to the state.

Two state DOTs use both a vendor proprietary and standard format (Hawaii and Virginia). The Hawaii DOT respondent added that depending on the sensor (such as LiDAR) and data, the agency uses a combination of both proprietary and standard formats with access via REST services to third parties. Minnesota DOT uses a format specific to agency asset attribution parameters, and Mississippi DOT uses a format specified in HPMS and PMS, depending on the asset.

Assessment of Agency Practices

Benefits

Eleven agencies indicated that implementing a coordinated statewide asset data collection and management approach enhanced their agencies' operations. The key benefits reported were improved performance, streamlined resources, a more comprehensive view of assets and opportunities for increased funding.

The Alabama DOT respondent noted that centrally organizing data collection efforts has allowed enterprise systems to more easily leverage extracted data. In New Hampshire, moving most roadside collection to iPads and Esri cloud facilitates standardization and makes upkeep easier. Governance structure and central coordination also help ensure that data can be maintained. The Utah DOT respondent noted the benefit of aligning time and data.

Other agency respondents noted the beneficial impact on economies of scale (Minnesota), less duplication of resources (Iowa and Mississippi) and increased awareness of issues with certain construction types (Kansas). The Virginia DOT respondent noted that as a result of the data collection processes, the agency has developed a needs-based maintenance and operations program budget since 2006. In 2017, the state's General Assembly provided additional funding for pavements and bridges, which began with presented needs from the data collected.

Challenges

The effort needed to coordinate data on an enterprise level is the most significant challenge experienced by respondents when using a statewide data collection and management approach (Alabama, Iowa, Minnesota, New Hampshire and Utah). Also challenging is addressing the different data needs of stakeholders and groups within the agency (Minnesota, Mississippi and North Carolina DPS). Additional issues include resources such as cost and staffing (Hawaii, Minnesota, New Hampshire and Virginia), and variable technologies, platforms and legacy data among districts (Minnesota).

Recommendations for Implementation

Nine agencies provided recommendations for other agencies developing a coordinated statewide program to collect and manage asset data. Most recommendations encouraged:

- Beginning with a strong foundation and consistent framework (Hawaii, Iowa, Minnesota, New Hampshire, Utah and Virginia).
- Establishing governance and coordination among stakeholders (Alabama, Iowa, Minnesota, New Hampshire, North Carolina DPS and Utah).
- Communicating to illustrate the benefits of this approach and to work through any challenges (Minnesota and Mississippi).

Related Research and Resources

A literature search of recent publicly available resources identified many national and state publications and resources related to data collection and management, and to remote and mobile data collection. An NCHRP project in progress anticipates developing a guide that compiles "principles, organizational strategies, governance mechanisms and practical examples for improving management of the processes for collecting data, developing useful information, and providing that information for decision making about management of the transportation system assets." A 2018 FHWA case study describes how state transportation agencies define data governance and data management, and policies for implementing these practices in GIS. Other 2018 FHWA case studies address mobile applications for GIS, and a 2018 FHWA report summarized discussions from a peer exchange that looked at policies, technical tools and strategies, and staffing for data governance. Other resources addressed the use of imaging, intelligent transportation systems and LiDAR in asset data collection and management.

Gaps in Findings

A limited number of survey respondents shared standards or procedures related to their agencies' statewide program to collect and manage asset data. Also, though nine agencies reported having a data quality management plan for data collection, only three agencies were able to provide these plans. The remaining agencies reported that plans were still in draft form, were not part of a formal written document or varied from asset to asset. State transportation agency response to the survey was also limited.

Next Steps

Moving forward, Caltrans could consider

- Examining the asset data collection and management standards, procedures and other resources provided by respondents for successful practices and policies.
- Reviewing the data quality management plans provided by Kansas, Mississippi and Utah DOTs.
- Following up with:
    - Utah DOT for online access to the agency's enterprise statewide program procedures (the public-facing web page is currently under construction).
    - Virginia DOT for access to the agency's data quality management plan.
    - Iowa, Minnesota, New Hampshire and New York State DOTs and North Carolina DPS for information about these agencies' data quality management plans.
- Contacting the respondent from Delaware, who provided only a partial response to the survey. Additional feedback from this agency, which has established a coordinated statewide approach to multiasset data collection and management, could prove useful as Caltrans begins to develop a strategic statewide plan.
- Engaging with South Carolina and Wyoming DOTs—agencies that are considering establishing a new asset data collection and management program or expanding their current practices to allow for a coordinated statewide approach.
- Gathering information from agencies that did not respond to the survey to obtain further guidance and perspectives.

Detailed Findings

Background

Some state departments of transportation (DOTs) have implemented a unified and coordinated statewide approach to project-specific and programmatic mass data collection and data management of agency assets. These collection efforts may employ a range of tools, including Global Positioning System (GPS) devices, multisensor mobile mapping platforms, airborne and terrestrial LiDAR, surface geophysics, unmanned aerial systems and photogrammetric processes.

The California Department of Transportation (Caltrans) would like to capitalize on the efficiencies gained through a "collect data once, use it many times" strategy. To facilitate transitioning to a coordinated statewide approach to data collection and management, Caltrans is seeking information from other state transportation agencies about current and best practices, and lessons learned as these agencies collect, extract and manage transportation asset and roadway characteristics data**.** The experiences of agencies with mature programs to collect and manage enterprise asset data are expected to inform development of a future Caltrans strategic statewide plan that will address the programmatic collection and management of field-collected roadway and roadside assets.

To assist Caltrans in this information-gathering effort, CTC & Associates conducted an online survey of state DOTs and other agencies that examined the asset data collection and management practices and policies of these agencies. A literature search of publicly available resources about national and state practices and guidance supplemented the survey findings. Results from these efforts are presented in this Preliminary Investigation in two areas:

- Survey of practice.
- Related research and resources.

Survey of Practice

An online survey was distributed to members of two American Association of State Highway and Transportation Officials (AASHTO) committees:

- Subcommittee on Asset Management.
- Committee on Performance-Based Management.

In addition, the survey was distributed to a representative of the North Carolina Department of Public Safety (North Carolina DPS) who was expected to have experience with a coordinated statewide approach to asset data collection and management.

Appendix A provides the survey questions. The full text of survey responses is presented in a supplement to this report.

Summary of Survey Results

Thirteen state DOTs responded to the survey:

- Alabama.
- Delaware (incomplete response).
- Hawaii.
- Iowa.
- Kansas.
- Minnesota.
- Mississippi.
- New Hampshire.
- New York.
- South Carolina.
- Utah.
- Virginia.
- Wyoming.

The North Carolina DPS representative also responded to the survey.

Of these 14 agencies, respondents from DOTs in 11 states—Alabama, Delaware, Hawaii, Iowa, Kansas, Minnesota, Mississippi, New Hampshire, New York, Utah and Virginia—and North Carolina DPS reported that their agencies have established a coordinated statewide approach to collecting and managing data on a range of agency assets.

Agencies in two states—South Carolina and Wyoming—have not established a coordinated statewide approach to multiasset data collection and management but are considering establishing a new program or expanding their current practices to allow for a coordinated statewide approach. The South Carolina DOT respondent noted that the agency is reviewing LiDAR collection, and if it proceeds with such a plan, the collection of assets and asset extraction "will almost certainly be performed by a contractor." Wyoming DOT is leveraging its biannual photolog of state routes to verify asset data previously gathered, such as for approaches, guardrails and signs. According to the Wyoming DOT respondent, the agency found that when it dispersed data collection and input, the consistency was not high enough to be reliable.

Below are findings from the 11 state transportation agencies and North Carolina DPS about their coordinated statewide approaches to asset data collection and management. Survey results are summarized in the following topic areas:

- Program description.
- Asset data collection.
- Asset data management.
- Assessment of agency practices.

Note: The respondent from Delaware DOT provided a partial response to the survey. Feedback from this agency is included in this Preliminary Investigation where available.

Program Description

Survey respondents provided the following information about their approach to asset data collection and management:

- Implementation of a coordinated statewide approach.
- Staffing.
- Frequency of data coordination and collection.
- Types of roadways.
- Published standards or procedures.

Implementation of a Coordinated Statewide Approach

Use of a coordinated statewide approach varied considerably among these agencies. More than half of the agencies responding to the survey have employed this approach for more than 10 years. Use ranged from 20 or more years (Delaware, Kansas, Minnesota, North Carolina DPS); approximately 30 years (Kansas and Mississippi); and more than 40 years (Iowa). The respondents from Kansas and Minnesota DOTs added that the length of time varies by asset class. The Minnesota DOT respondent also noted that "success has not been universal."

The remaining five agencies (Alabama, Hawaii, New Hampshire, New York and Utah) have used this approach to asset data collection and management for less than 10 years. Survey results are summarized in Table 1.

Table 1. Implementation of a Coordinated Statewide Approach

State	0 to 2 Years	2 to 5 Years	7 to 10 Years	Other	Description
Alabama		X			N/A
Delaware				X	More than 20 years.
Hawaii			X		N/A
Iowa				X	More than 40 years, although processes have evolved.
Kansas				X	• *Pavement*: 30+ years. • *Bridges*: 20+ years.
Minnesota				X	Varies by asset class: • *Signs*: 20 years with poor success. • *Drainage culverts*: 20 years with good success. • *Traffic barriers*: 2 years. • *Traffic signals/ITS*: 10+ years.
Mississippi				X	Nearly 30 years (since 1991).
New Hampshire	X				N/A
New York	X				N/A
North Carolina DPS				X	Approx. 20 years (since 2000).
Utah			X		N/A
Virginia				X	More than 12 years.
Total	**2**	**1**	**2**	**7**	

Staffing

Eight agencies use both consultants and in-house staff to collect, store and analyze data, depending on the task and the asset (Alabama, Delaware, Minnesota, Mississippi, New Hampshire, New York, North Carolina and Virginia). In Alabama, an in-house LiDAR crew collects data for smaller projects, while contractors collect data for larger projects and perform most data extraction. New Hampshire DOT's data flows to an Esri cloud service (for most assets) or to a special service (pavement). Data is then returned to the agency and integrated in its GIS. The North Carolina DPS respondent reported that a contractor collects and stores data in the state, and in-house staff performs quality control, analysis and use.

Three states use consultants only (Hawaii, Iowa and Utah), and one state uses in-house staff only (Kansas). Survey results are summarized in Table 2.

Table 2. Responsibility for Multiasset Data Collection and Management

State	Consultant/ Contractor	In House Staff	Other	Description
Alabama			X	• An in-house LiDAR crew runs smaller projects and contractors run larger projects. • Most extraction is performed by consultants.
Delaware			X	• Consultants and in-house staff collect, store and analyze data, depending on the asset and asset owner. • In-house staff collects most asset data sets related to Highway Performance Monitoring System (HPMS) reporting.
Hawaii	X			N/A
Iowa	X			N/A
Kansas		X		N/A
Minnesota			X	• Asset Management Program Office coordinates data acquisition and maintenance, working with specialty offices (asset program managers) and district personnel to acquire and maintain data, including construction as-built and maintenance crew modifications to assets. • Many data acquisition and maintenance techniques used: ○ Construction and GIS staff maintain legacy asset data. ○ Consultants conduct construction-related field surveys. ○ Internal staff uses field devices for some collection. ○ Asset management system work orders used for asset data updating. ○ Statewide LiDAR contract implemented for asset data collection and extraction.
Mississippi			X	Both consultants and in-house staff collect and analyze data.
New Hampshire			X	Collection depends on the asset: • *Most assets*: Data flows to an Esri cloud service. • *Other assets* (e.g., pavement): Data managed by a special service. • Data is returned to DOT and integrated in GIS.
New York			X	• Consultant collects data. • In-house staff stores data in a geographical data warehouse.
North Carolina DPS			X	• Contractor collects and stores data. • In-house staff performs quality control, analysis and use.
Utah	X			N/A
Virginia			X	Consultants and in-house staff compile and analyze data. DOT stores data.
Total	**3**	**1**	**8**	

Frequency of Data Coordination and Collection

At the enterprise level, half of the agencies coordinate and collect data annually. Collection cycles vary for the remaining six agencies. None of the states responding to the survey collect data every two years or every three years, although Alabama DOT is aiming for a three-year cycle. The respondent from Minnesota DOT reported that coordination occurs continuously and varies by priority and effect on asset data quality. He added that the agency philosophy is to "collect data once and maintain its currency on an ongoing basis in real time." The North Carolina DPS respondent noted that imagery is collected one quarter of each year and LiDAR is collected approximately every 10 years or as needed. Table 3 summarizes survey results.

Table 3. Frequency of Data Coordination and Collection

State	Annually	Other	Description
Alabama		X	• Collection cycle still evolving. • Data Collection Section plans to formalize schedule this year and is aiming for a three-year cycle (could run up to five years).
Delaware		X	N/A
Hawaii	X		N/A
Iowa	X		N/A
Kansas	X		N/A
Minnesota		X	• Coordination occurs continuously and varies by priority and effect on asset data quality. • Agency philosophy: Collect data once and maintain its currency on an ongoing basis in real time.
Mississippi		X	• HPMS: Annually. • Pavement management system (PMS): Every two years.
New Hampshire		X	Asset-specific.
New York	X		N/A
North Carolina DPS		X	• Imagery: One quarter each year. • LiDAR: Approx. every 10 years or as needed.
Utah	X		N/A
Virginia	X		N/A
Total	**6**	**6**	

Type of Roadways

Respondents from 11 agencies indicated the types of roadways where asset data is collected including:

- All public roads.
- State roadways.
- Local roadways.
- National Highway System (NHS) only.
- Ramps and connectors.

Asset data is most commonly collected on state roads (Alabama, Hawaii, Kansas, Minnesota, Mississippi, New York, Utah and Virginia) followed by all public roads (Iowa, New Hampshire, North Carolina DPS and Virginia) and ramps and connectors (Hawaii, Minnesota, New Hampshire and Virginia).

The Hawaii DOT respondent added that the agency collects data from county collector roads and above. In Mississippi, the agency gathers data on all state-maintained routes plus various routes on functionally classified roads for HPMS reporting. The respondent added that a contractor extracts some roadway features. In New Hampshire, data collection depends on the asset, but the focus is state roads for most assets. Table 4 summarizes survey results.

Table 4. Type of Roadway for Asset Collection

State	All Public Roads	State Roads	Local Roads	NHS only	Ramps/ Connectors	Other	Description
Alabama		X					N/A
Hawaii		X	X	X	X	X	County collector roads and above.
Iowa	X						N/A
Kansas		X	X				N/A
Minnesota		X			X		N/A
Mississippi		X				X	• All state-maintained routes. • Various routes on functionally classified roads for HPMS reporting. • Contractor extracts some roadway features.
New Hampshire	X				X	X	• Asset-dependent. • Focus is state roadways for most assets.
New York		X					N/A
North Carolina DPS	X						N/A
Utah		X		X			N/A
Virginia	X	X		X	X		N/A
Total	**4**	**8**	**2**	**3**	**4**	**3**	

Published Standards or Procedures

Eight agencies—Iowa, Kansas, Minnesota, Mississippi, New Hampshire, North Carolina DPS, Utah and Virginia—have adopted or published standards or procedures for collecting and managing asset data from their enterprise statewide programs. Four agencies provided documentation for these standards and procedures (see Related Resources below).

Respondents from Minnesota, Mississippi and New Hampshire DOTs noted that procedures and practices are available internally as their agencies work to create or standardize them. Additional information provided by respondents follows:

Iowa. The agency currently uses a vendor to extract data from imagery and request updates from local agencies annually. The agency's data dictionary provides specifications of its current system (see Related Resources below).

Minnesota. The respondent noted that standards and procedures in Minnesota vary by asset class and methodology, and are available in various documents but no one single source. For example, LiDAR survey standards are part of a contract; as-built procedures are published; data maintenance expectations for signs and hydraulics processes are published as part of the asset management system implementation (see Related Resources below).

Mississippi. Mississippi DOT is working on data governance as an agency. Current resources are the HPMS Field Manual (see Related Resources below) and the DOT's PMS procedures.

New Hampshire. The agency is currently standardizing its procedures. Elements have been published and are used internally.

North Carolina DPS. The respondent noted that the agency has developed issue papers that describe LiDAR data collection practices and explain how issues have been resolved. *Note*: She directed us to search for "LiDAR" at the agency's document center (https://flood.nc.gov/ncflood/documentcenter.html?type=10) to access these issue papers. These publications (dated from 2001 to 2005) are provided in Related Resources below.

Utah. The agency is currently updating its web page to include the agency's enterprise statewide program procedure.

Virginia. The Virginia DOT respondent said the agency has extensively documented the processes for pavement and bridge data collection. The respondent did not respond to follow-up requests to gather this documentation.

Related Resources

Multiple States

Highway Performance Monitoring System Field Manual, Federal Highway Administration, December 2016.
Field manual: https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/
HPMS program: https://www.fhwa.dot.gov/policyinformation/hpms.cfm
The HPMS program is a "national level highway information system that includes data on the extent, condition, performance, use and operating characteristics of the nation's highways. The HPMS contains administrative and extent of system information on all public roads, while information on other characteristics is represented in HPMS as a mix of universe and sample data for arterial and collector functional systems. Limited information on travel and paved miles is included in summary form for the lowest functional systems." The field manual "provides a comprehensive overview of the HPMS program, and describes in detail the data collection and reporting requirements for HPMS. … The HPMS Field Manual is a valuable resource that guides the States as they address their HPMS data collection and reporting responsibilities. This manual includes detailed information on technical procedures, a glossary of terms, and various tables to be used as reference by those collecting and reporting HPMS data.

Hawaii

2018 State of Hawaii Service Project Data Dictionary, Hawaii Department of Transportation, December 2018.
See Attachment A.
This document provides a classification of condition data reported by the agency.

Iowa

Geodatabase Documentation, Iowa Department of Transportation, October 2018.
See Attachment B.
Iowa DOT has developed this data dictionary to define the specifications of its current system and standardize communication of roadway data.

Kansas

Pavement Management Information System (PMIS), Kansas Department of Transportation, January 2020.
http://www.ksdot.org/matreslab/pmis/reports.asp
This web page provides links to district and state maps of performance, remaining life, roughness, transverse cracking, joint distress, rutting and faulting. The web page also briefly describes the legend used for each map (for example, good/fair/poor pavement surface conditions).

Minnesota

Note: Though not provided by the respondent, the following publication may be of value to Caltrans.

Transportation Asset Management Plan, Minnesota Department of Transportation, June 2019.
www.dot.state.mn.us/assetmanagement/pdf/tamp/tamp.pdf
From page 4 of the plan (page 10 of the PDF): [The transportation asset management plan (TAMP)] is a planning tool to help MnDOT further evaluate risks, develop mitigation strategies, analyze life cycle costs, establish asset condition performance measures and targets, and develop investment strategies. The TAMP formalizes and documents the following key information to meet federal requirements:

- Description and condition of pavements and bridges on the NHS.
- Asset management objectives and measures.
- Summary of gaps between targeted and actual performance.
- Life cycle cost and risk management analysis.
- Financial plan that addresses performance gaps.
- Investment strategies and anticipated performance.

North Carolina

Note: The following issue papers, recommended by the survey respondent, address three phases of a project to define the use of LiDAR for collecting elevation data sets for land mapping and provide LiDAR specifications. The papers were produced from 2001 to 2005 and are available at https://flood.nc.gov/ncflood/documentcenter.html?type=10. (Under Document Type, select “Issue Papers.” Enter “LiDAR” in the search field.)

Issue 50: Phase III Quality Control of Light Detection and Ranging (LiDAR) Elevation Data in North Carolina, North Carolina Cooperating Technical State Mapping Program, February 2005.
https://flood.nc.gov/NCFLOOD_BUCKET/ISSUE/ip50_final_phaseIII_lidar_qc.pdf

Issue 37: Quality Control of Light Detection and Ranging (LiDAR) Elevation Data in North Carolina for Phase II of the NCFMP, North Carolina Cooperating Technical State Mapping Program, February 2004.
https://flood.nc.gov/NCFLOOD_BUCKET/ISSUE/IP37-phaseII_lidar_qc.pdf

Issue 5: Quality Control of Light Detection and Ranging (LIDAR) Elevation Data in North Carolina, North Carolina Cooperating Technical State Mapping Program, October 2001.
https://flood.nc.gov/NCFLOOD_BUCKET/ISSUE/IP05-lidar_qc.pdf

Issue 7: Light Detection and Ranging (LIDAR) Specifications, North Carolina Cooperating Technical State Mapping Program October 2001.
https://flood.nc.gov/NCFLOOD_BUCKET/ISSUE/IP07-lidar_spec.pdf

Asset Data Collection

Respondents provided information about the following general practices and policies of their agencies' asset data collection program:

- Core set of assets.
- Data collection and extraction methods.
- Data collection and coordination practices.
- Data quality management plan.

Core Set of Assets

Using the following list of asset types, respondents from 11 agencies described the core assets of data collection efforts:

- Barrier (i.e., guardrail).
- Bridges.
- Cabinets.
- Drainage features/culverts.
- Intelligent transportation systems (ITS).
- Lands and buildings.
- Loop detectors.
- Marking reflectivity.
- Model Inventory of Roadway Elements (MIRE).
- Pavement.
- Pavement markings.
- Ramp meters.
- Right of way (ROW).
- Roadside facilities.
- Roadside features.
- Sign reflectivity.
- Signal post.
- Signs.
- Structures/walls.
- Other.

All 11 agencies collect data for bridges and pavement. Other assets that are commonly monitored are barriers (Alabama, Hawaii, Iowa, Minnesota, New Hampshire, New York, Utah and Virginia); drainage features (Hawaii, Iowa, Kansas, Minnesota, New Hampshire, New York,

Utah and Virginia); and signs (Alabama, Hawaii, Iowa, Minnesota, New Hampshire, New York and Utah). None of the 11 agencies collect data on loop detectors. Agencies are least likely to collect data on cabinets, lands and buildings, marking or sign reflectivity, ramp meters, rights of way and roadside facilities.

Utah DOT collects data on the most asset types (17), followed by Hawaii and Minnesota DOTs (13 each) and New Hampshire DOT (12). Agencies collecting data on the least number of asset types are Kansas DOT (three) and North Carolina DPS (two).

Four respondents described additional information about asset data collection efforts. The respondent from Hawaii DOT noted the agency's online resources for asset management that indicate the LiDAR used and features collected in 2019 (see *Related Resources* below). Mississippi DOT collects data for "anything required by HPMS." Other asset types listed were overhead signs and rock slopes (New Hampshire) and cattle guards (Utah). Survey results are summarized in Tables 5A and 5B.

Table 5A. Core Asset Data Collected by Agencies

State	Barrier	Bridges	Cabinets	Drainage Features	ITS	Lands/ Buildings	Marking Reflectivity	MIRE	Pavement	Pavement Markings
Alabama	X	X							X	
Hawaii	X	X		X			X	X	X	X
Iowa	X	X		X				X	X	
Kansas		X		X					X	
Minnesota	X	X	X	X	X		X		X	X
Mississippi		X	X		X			X	X	
New Hampshire	X	X		X	X	X		X	X	
New York	X	X		X					X	X
North Carolina DPS		X							X	
Utah	X	X	X	X	X	X	X		X	X
Virginia	X	X		X		X			X	
Total	**8**	**11**	**3**	**8**	**4**	**3**	**3**	**4**	**11**	**4**

Table 5B. Core Asset Data Collected by Agencies

State	Ramp Meters	ROW	Roadside Facilities	Roadside Features	Sign Reflec tivity	Signal Post	Signs	Structures or Walls	Other	Description
Alabama				X			X	X		N/A
Hawaii				X	X	X	X	X	X	See *Related Resources* below for details about 2019 assets.
Iowa				X			X	X		N/A
Kansas										N/A
Minnesota	X			X	X	X	X			N/A

State	Ramp Meters	ROW	Roadside Facilities	Roadside Features	Sign Reflectivity	Signal Post	Signs	Structures or Walls	Other	Description
Mississippi									X	Anything required by HPMS.
New Hampshire		X	X	X			X		X	• Overhead signs (not all signs). • Rock slopes.
New York							X	X		N/A
North Carolina DPS										N/A
Utah	X		X	X	X	X	X	X	X	Cattle guards.
Virginia	X	X	X			X		X		N/A
Total	**3**	**2**	**3**	**6**	**3**	**4**	**7**	**6**	**4**	N/A

Related Resources:

Roadview Explorer 5 Manual, Hawaii Department of Transportation, 2020.
https://rvx.mandli.com/hawaii/help/index.php
This web page provides links to information about asset data collected by Hawaii DOT in 2019 using the Roadview Explorer application. Five help videos include an introduction to the software; methods to search for assets, view them in Photolog and navigate the program; methods to view and sort pavement data based on customizable criteria; and a case study. Other links provide access to user documentation and features of the application.

"Asset Management," Roadview LiDAR Viewer, Hawaii Department of Transportation, undated.
See Attachment C.
Adding and editing assets are discussed in this brief help resource for users.

Data Collection and Extraction Methods

Respondents indicated which of the following technology and tools are used by their agencies to collect and extract asset data:

- GPS devices.
- LiDAR (airborne).
- LiDAR (terrestrial).
- Manual data collection.
- Mobile devices (smartphone, tablet).
- Multisensor mobile mapping platforms.
- Photogrammetric processes.
- Photolog.
- Surface geophysics.
- Unmanned aerial systems (UAS).
- Windshield survey.
- Other.

All of the 11 agencies except New York State DOT use GPS devices in asset data collection and extraction. Other commonly used technology and tools are terrestrial LiDAR (Alabama, Hawaii, Iowa, Kansas, Minnesota, Mississippi, North Carolina DPS and Utah); manual data collection (Iowa, Kansas, Minnesota, Mississippi, New Hampshire, North Carolina DPS, Utah

and Virginia); and mobile devices (Alabama, Iowa, Minnesota, Mississippi, New Hampshire, Utah and Virginia). Tools and technology least used are airborne LiDAR, photogrammetric processes and surface geophysics.

The Utah DOT respondent noted that UAS use for data collection and extraction is experimental. The Hawaii DOT respondent noted that the agency also uses the laser crack measurement system (LCMS) to collect pavement condition data (see **Data Quality Management Plan**, page 22, for information about Hawaii DOT's use of LCMS).

Iowa and Utah DOTs use the most tools and technologies to collect and extract data (eight each) followed by Mississippi DOT and North Carolina DPS (seven each). Agencies using the least number of tools and technologies are Kansas (three) and New York State (two) DOTs. Survey results are summarized in Tables 6A and 6B.

Table 6A. Methods Used to Collect and Extract Asset Data

State	GPS Devices	LiDAR (Airborne)	LiDAR (Terrestrial)	Manual Data Collection	Mobile Devices	Multisensor Mobile Mapping Platforms	Photogram metric Processes
Alabama	X		X		X		
Hawaii	X		X			X	
Iowa	X		X	X	X		X
Kansas	X		X	X			
Minnesota	X		X	X	X		
Mississippi	X	X	X	X	X		X
New Hampshire	X			X	X		
New York						X	X
North Carolina DPS	X	X	X	X		X	
Utah	X	X	X	X	X	X	
Virginia	X			X	X		
Total	**10**	**3**	**8**	**8**	**7**	**4**	**3**

Table 6B. Methods Used to Collect and Extract Asset Data

State	Photolog	Surface Geophysics	UAS	Windshield Survey	Other	Description
Alabama	X		X	X		N/A
Hawaii					X	LCMS for pavement condition data.
Iowa	X		X	X		N/A
Kansas						N/A
Minnesota						N/A
Mississippi	X					N/A
New Hampshire		X	X[1]			N/A
New York						N/A

State	Photolog	Surface Geophysics	UAS	Windshield Survey	Other	Description
North Carolina DPS			X	X		N/A
Utah	X			X		N/A
Virginia	X			X		N/A
Total	**5**	**1**	**4**	**5**	**1**	

1 UAS data collection in Utah is experimental.

Data Collection and Coordination Practices

Survey respondents from 11 agencies briefly described data collection and coordination practices, including:

- Whether contractors or in-house staff performed data collection, extraction and management.
- Whether agencies collected asset data during project delivery phases (from design through construction) and entered the data into asset management information systems for future use.
- How agencies coordinated statewide data collection with other groups or units, meeting the competing demands for the type and extent of asset data without duplicating efforts.

Highlights of survey responses follow and are summarized in Table 7.

Responsibility for Data Collection, Extraction and Management

Ten of the 11 respondents reported that both agency staff and contractors perform the field asset data collection, extraction and management efforts within their agencies, depending on the asset. New York State DOT uses contractors only for these functions. None of the participating agencies use agency staff only.

Collecting Data During Project Delivery Phases

Agencies in six states—Iowa, Kansas, Minnesota, New Hampshire, New York and Virginia—collect asset data during project delivery phases (design through construction). This data is then entered into asset management information systems for future use.

Coordinating Data Collection to Avoid Duplication

Enterprise coordination with other functional areas is the primary practice reported by respondents to avoid duplication and still meet the competing demands for the type and extent of asset data, although the Alabama DOT respondent noted that "[it] is hard to say that there is no duplication." In most cases, specific business units within each agency coordinate data collection:

- Alabama: Data Collection Section of the Maintenance Bureau.
- Minnesota: Asset Management Project Office, with active participants in statewide functional organizations such as traffic engineers, maintenance engineers and GIS specialists.
- New Hampshire: Central asset management office.

Utah and Virginia DOTs distribute responsibility among multiple divisions and champions. Hawaii DOT has developed a data dictionary and tools that are used throughout the agency by functional units such as maintenance, design and safety.

The Mississippi DOT respondent noted that the agency's Planning and Research divisions use the same contract for HPMS and PMS data collection and extraction. North Carolina DPS coordinates large-scale data collection with the North Carolina Geographic Information Coordinating Council, an organization within the North Carolina Department of Information Technology that promotes GIS technology and the "value of reliable geographic information for effective decision making" (see *Related Resource* below). Table 7 summarizes survey results.

Table 7. Data Collection and Coordination Practices

State	Contractor Collects Data	Staff and Contractor Collect Data	Data Collected During Project Phases	Description of Coordination Efforts
Alabama		X		Data Collection Section of the Maintenance Bureau coordinates data collection of assets leveraged in enterprise GIS, though "it is hard to say that there is no duplication."
Hawaii		X		Development of agencywide data dictionary and tools that utilize the data needed by various offices (such as maintenance, design and safety).
Iowa		X	X	Enterprise coordination.
Kansas		X	X	• Agency staff responsible for all data collection except local bridge inspection data. • Bridge inspection data collected by consultants.
Minnesota		X	X	• Coordination through Asset Management Project Office (AMPO), which is responsible for understanding the various needs and uses of data through involvement with stakeholders and subject matter experts. • Active participants in statewide functional organizations, such as traffic engineers, maintenance engineers and GIS specialists.
Mississippi		X		Planning and Research divisions use same contract for HPMS and PMS data collection and extraction (if needed).
New Hampshire		X	X	Governance structure and central asset management office.
New York	X		X	N/A
North Carolina DPS		X		Partnership with the North Carolina Geographic Information Coordinating Council to coordinate large-scale data collection (see *Related Resource* below).

State	Contractor Collects Data	Staff and Contractor Collect Data	Data Collected During Project Phases	Description of Coordination Efforts
Utah		X		• Single project manager coordinates data for multiple groups. • For structures and pavement data, champions from each division coordinate with the project manager.
Virginia		X	X	Responsibility assigned to various divisions and areas of expertise.
Total	**1**	**10**	**6**	

Related Resource:

North Carolina Geographic Information Coordinating Council, North Carolina Department of Information Technology, undated. https://it.nc.gov/about/boards-commissions/north-carolina-geographic-information-coordinating-council
From the web site: The North Carolina Geographic Information Coordinating Council (GICC) was established by the NC [North Carolina] General Assembly to develop policies regarding the use of geographic information, geographic information systems (GIS), and related technologies. The Council is an organization of volunteers whose goals are to:

- Collaborate in geographic information and systems involving state, federal and local government agencies, academic institutions, private organizations and individuals across the state.
- Improve the quality, access, cost-effectiveness and utility of North Carolina's geographic information and resources, and promote geographic information as a strategic resource.
- Efficiently collect, develop and use geographic information through voluntary exchange and sharing of data and technical know-how.
- Explore, guide and provide a framework for coordination including:
  - Developing standards.
  - Planning strategically.
  - Resolving policy and technical issues.
  - Providing central direction and oversight.
  - Advising the Governor and the Legislature as to needed directions, responsibilities and funding regarding geographic information.

Data Quality Management Plan

Nine agencies have a data quality management plan for data collection. Respondents from agencies in four of these states—Kansas, Mississippi, Utah and Virginia—reported having a plan that can be shared. See below for data quality management plans provided by respondents from all of these agencies except Virginia DOT; the respondent from that agency did not respond to follow-up requests for the plan.

Five agencies—Iowa, Minnesota, New Hampshire and New York State DOTs and North Carolina DPS—have a plan but can't share it. The respondent from Minnesota DOT noted that

data quality management plans vary by asset and are not documented within a single source. New Hampshire DOT's data quality management plan is currently in draft form. The North Carolina DPS respondent reported that the plan is not a formal written document.

The respondents from Alabama and Hawaii DOTs reported that their agencies do not have a plan. The Hawaii DOT respondent did provide the agency's management plan for quality pavement condition data.

Hawaii

Management Plan for Quality Pavement Condition Data, Highways Planning Survey Section, Hawaii Department of Transportation, January 2019.
See Attachment D.
From the plan goals (page 2 of the report, page 3 of the PDF):

> This management plan begins by defining what data needs to be collected, how it will be collected, as well as how it will be reported and maintained after it is collected. Additionally, this plan will cover the process for reviewing and checking the data for acceptance, as well as all of the quality control measures required to assure the data is accurate and complete. This plan includes a contractor data quality management plan that describes the data collection equipment, calibration, certification, and operator training used to collect pavement condition data at highway speeds for HDOT [Hawaii DOT]. This document also includes the contractor's quality control measures conducted before and during the data collection, during the data processing, and the checks to assure data completeness and validity.

Other topics include data collection (page 3 of the report, page 4 of the PDF), data metrics and protocols (page 6 of the report, page 7 of the PDF), and data issues (page 8 of the report, page 9 of the PDF).

LCMS, which is used for the pavement condition survey, is briefly discussed on page 3 of the plan (page 4 of the PDF)*:*

> The distress data will be collected using a 3D pavement scanner, a laser crack measuring system (LCMS), driven at highway speeds and processed with automated analysis. There will not be any manual data collection for the SHS [state highway system] or other routes annually collected.

A metric involving LCMS is discussed on page 6 of the plan (page 7 of the PDF):

> **Faulting for jointed concrete pavements**: Faulting computed based on AASHTO Standard R36-13 with the parameters specified in the HPMS Field Manual, using data measured with LCMS sensors.

Kansas

Kansas Pavement Condition Data Collection Quality Management Plan, Pavement Management, Kansas Department of Transportation, 2018.
See Attachment E.
Kansas DOT's quality management plan addresses the data collection process (beginning on page 4 of the report), including collection vehicles, staff responsible for collecting data and quality control activities before and during data collection. Also included are discussions of the data processing and reporting processes (beginning on pages 10 and 12, respectively).

Mississippi

Appendix 1: Pavement Management Manual, Development of a Pavement Management Manual and Data Quality Plan for the Mississippi Department of Transportation, Mississippi Department of Transportation, Gregory M. Duncan, Luis M. Sibaja Vargas, Prashant K. Ram and Kathryn A. Zimmerman, June 2017.
https://mdot.ms.gov/documents/Research/Reports/Interim%20&%20Final/State%20Study%20268%20-%20Development%20of%20a%20Pavement%20Management%20Manual%20and%20Data%20Quality%20Plan%20for%20MDOT.pdf
The Pavement Management Manual is Appendix 1, beginning on page 57 of the PDF. Chapter 5 of the manual (page 78 of the PDF) describes the functional classification system for maintenance and rehabilitation. Current pavement management data collection practices are discussed in Chapter 6 (beginning on page 82 of the PDF). Additional topics include pavement performance modeling (Chapter 7, page 86 of the PDF), treatment selection (Chapter 8, page 88 of the PDF) and pavement management reporting (Chapter 9, page 92 of the PDF).

Utah

Quality Management Plan, Utah Department of Transportation, 2017.
https://docs.google.com/a/utah.gov/viewer?a=v&pid=sites&srcid=dXRhaC5nb3Z8cGF2ZW1lbnR8Z3g6MzU2NjkzZDg2ZjE5OWUyNQ
This plan describes the high-speed data collection and reporting activities of Utah DOT's asset management contractor (Mandli Communications). *From the executive summary*:

> The QM [quality management] plan outlines practices in place throughout the service project collection and processing efforts. It describes the roles and responsibilities for successful QM of a service project and presents examples of practices currently in use by Mandli for Quality Control (QC). Creating and maintaining an effective QM plan for Mandli service work includes specifying the data collection rating protocols to be used, establishing quality standards and acceptance criteria, identifying responsibilities, performing QC activities, monitoring and testing for acceptance, taking timely and appropriate corrective actions, and performing QM reporting.

Flowcharts on page 3 of the PDF illustrate the vehicle configuration and calibration predeployment activities along with data collection and extraction. A discussion of data collection begins on page 11 of the PDF; a discussion of data reduction and extraction begins on page 19 of the PDF. Appendix A summarizes the collection system configuration (photolog, positional orientation, LiDAR and LCMS) (page 25 of the PDF).

Related Resources

Below are resources related to agencies' statewide asset data collection and management efforts that were provided by respondents or obtained through a limited literature search.

Hawaii

"A Plan for Every Section of Every Road on Every Island," Goro Sulijoadikusumo, *12th Annual National Conference on Transportation Asset Management*, July 2018.
http://onlinepubs.trb.org/onlinepubs/Conferences/2018/AssetManagement/SulijoadikusumoAPlanforEverySectionofEveryRoad.pdf
This presentation discusses the history of the road information system project conducted on the Hawaiian Islands. It includes information on the technology used to gather data, reporting tools and the use of the data for project prioritization.

Use of 3D Digital for Asset Management, *3D Engineered Models: Schedule, Cost and Post-Construction*, Every Day Counts, Federal Highway Administration, April 26, 2016.
https://connectdot.connectsolutions.com/p1ruf5vg9yn/?launcher=false&fcsContent=true&pbMode=normal
Complete series: https://www.fhwa.dot.gov/construction/3d/edc3webinars.cfm
This webinar is one of seven webinars created by Federal Highway Administration under the third round of the Every Day Counts initiative to assist transportation agencies in adopting 3D engineered models. This presentation addresses the use of LiDAR and other tools for asset management.

"Integration of Point Cloud Data and Photo-Log Images of Highways Within VR-Design Studio," Goro Sulijoadikusumo, *FORUM8 International VR Symposium*, Users Report, Vol. 107, 2014.
http://www.forum8.co.jp/user/user107-e.htm
This presentation describes Hawaii DOT's use of the point-cloud Photo Processing Extension (PPE) plug-to add color to the point cloud data collected, using pixel data from the photo-log images of the target roads and surrounding structures.

Photolog to Digilog: 3D Asset Management, Hawaii Department of Transportation and Mandli Communications, 2014.
http://www.heep.org/conference/archive/2014/files/presentations/photolog_to_digilog.pdf
This presentation examines various data collection technologies and asset inventories.

Mandli X-35, Mandli Communications, 2020.
https://www.mandli.com/solutions/mandli-x-35/
This vendor web site describes the features and functions of the data collection vehicle used by the Hawaii DOT contractor.

Roadview: Data Collection and Processing, Roadview, Inc., 2020.
https://www.roadview.com/
This vendor web site describes Roadview, "an industry leader in the collection, reduction and delivery of large-scale, geo-referenced transportation data sets."

Iowa

Guide to Life-Cycle Data and Information Sharing Workflows for Transportation Assets, David Jeong, Charle Jahren, Jennifer Shane, Kristen Cetin, Tuyen Le and Chau Le, Iowa Department of Transportation, Midwest Transportation Center and U.S. Department of Transportation, September 2018.
http://publications.iowa.gov/28264/1/TR-714_Final%20Report_guide_to_life-cycle_data_and_info_sharing_w_cvr.pdf
From the abstract:

> The purpose of this research was to identify current data workflows and areas for improvement for five of the most common types of highway assets—signs, guardrails, culverts, pavements and bridges—and offer guidance to practitioners on how to better collect, manage and exchange asset data.

From the report's conclusions beginning on page 86 of the report (page 100 of the PDF):

- The research team's interviews with highway professionals revealed that asset maintenance personnel are required to manually locate data in project documents and merge the data into asset management systems. In many cases, asset inventory data

must be collected a second time from the field using mobile devices. Properly transferring the appropriate asset data in the right format to the operation and maintenance phases will reduce the costs of duplicating data collection efforts, which will, in turn, enhance productivity and reduce operation costs.

- An extensive review of the literature, manuals, project documents and software applications centering on data attributes was also conducted. These data were refined and organized in IDM [information delivery manual] documents in which the processes and data exchange relationships among the project players were visually represented. The study developed five separate IDMs for five different types of assets. Each IDM is composed of several PMs [process maps] and one ER [exchange requirement] matrix. In total, 15 PMs and 5 ER matrices were developed.
    - PMs can help practitioners better understand the work process and interactions between involved parties for different types of projects (i.e., new construction, reconstruction, repair and maintenance).
    - ER matrices showed who needs what data and who can provide the data.
- An ideal process map and suggestions for improvement were proposed to further streamline the workflows throughout the project life cycle and reduce duplicate data collection efforts during the operation and maintenance phases.

New, Web-Based System to Better Interconnect Iowa DOT Data, Blog Post, *Transportation Matters for Iowa*, Iowa Department of Transportation, July 2017.
https://www.transportationmatters.iowadot.gov/2017/07/new-web-based-system-to-better-interconnect-iowa-dot-data-.html
From the blog post: The Iowa Department of Transportation has long been a leader in the collection of transportation data, including things like traffic volumes, lane width and sufficiency ratings. Many custom data systems have been developed by or for us that use the latitude and longitude of the centerlines of every public roadway to give a common linear reference point to tie together many types of data. These systems, most notably the Geographic Information Management System (GIMS), provided access to a variety of information, but were sometimes complex to use and required a desktop application to access the data. In our quest to be smarter, simpler and customer driven, the interface for accessing many of the data sets is moving away from GIMS to a mobile-friendly web-based environment we are calling the Roadway Asset Management System (RAMS).
….
RAMS uses a commercially available geographic information system (GIS) product called Roads and Highways as its foundation. Roads and Highways was developed by ESRI, a GIS mapping software company the Iowa DOT has worked with extensively over the years and provides a universal method to locate our business data.

Iowa DOT's RAMS Administrator Mike Clement points out the "off-the-shelf" system will be much more user-friendly and allow any Iowa DOT employee with internet access and logged into the Iowa DOT's network to view, analyze and manage data in the field.

Ryan Wyllie, with the Office of Research and Analytics, says, "As more data sets are brought into the system, they can easily be tied together for analysis purposes. For example, we can take our deer kill data and merge it with crashes, lighting and signing. We might see that instead of just needing to post a sign in an area with high deer hits, perhaps we should look at putting a new light in the area."

The team says using Road and Highways will also make updating data simpler be moving from a manual to an automated process. Clement said, “When there are any road changes, one update to the system will automatically make the same change across all data sets. Right now, users have to do a lot of manual updating.”

Utah

“Using Aerial LiDAR Technology to Update Highway Feature Inventory: Utah Department of Transportation,” *GIS in Transportation*, Federal Highway Administration, Spring 2017. (See pages 1-3 for the newsletter article cited.)
https://www.gis.fhwa.dot.gov/newsletters/Newsletter_Spring2017.pdf
This newsletter article briefly describes one of Utah DOT's GIS initiatives—the LiDAR-based Maintenance Feature Inventory. The agency uses mobile LiDAR data and airborne mapping “to provide effective information about road assets.” *From the newsletter*:

> **How has the use of the application/geospatial technologies met the transportation, business and/or technical needs of your agency or department? How do you know?**
>
> State DOTs and transportation agencies are always looking for better techniques to reduce costs. Airborne LiDAR is much faster in data collection than conventional surveying methods. This project further demonstrated that the point density of airborne LiDAR data is sufficient for most highway assets. Also, airborne LiDAR has the advantage over ground-based inventory technologies of providing a different perspective; as a result, it can detect objects like bridges and culverts that may be hidden from the mobile platform (see Figures 2a and 2b). In addition, the data processing procedure proposed in this project improved the efficiency of airborne LiDAR. We conclude that airborne LiDAR is a highly promising technique that can serve as a complement to other techniques for highway inventory data collection.

“Highway Asset Inventory Data Collection Using Airborne LiDAR,” Yi He, Ziqi Song and Zhaocai Liu, *Transportation Research Board 96th Annual Meeting*, Paper #17-04058, 2017. Citation at https://trid.trb.org/view/1438599
From the abstract: The focus of this paper is to analyze the capability and strengths of airborne LiDAR in highway inventory data collection. A field experiment was conducted to collect airborne LiDAR data, and an ArcGIS-based algorithm was proposed to process the data. The results demonstrate the effectiveness of our proposed algorithm as well as the feasibility and high efficiency of airborne LiDAR for highway inventory data collection.

Related Resource:

> **“Highway Asset Inventory Data Collection Using Airborne LiDAR,”** Yi He and Ziqi Song, *SELECT Annual Meeting and Technology Showcase*, September 2016.
> https://conference.usu.edu/selectshowcase/includes/Posters/TransportationInfrastructure/Highway%20Asset%20Inventory%20Data%20Collection%20Using%20Airborne%20LiDAR.pdf
> This poster for an unrelated conference describes the project addressed in the TRB conference paper cited above.

Implementation of Aerial Lidar Technology to Update Highway Feature Inventory, Yi He, Ziqi Song, Zhaocai Liu and Rukhsana Lindsey, Utah Department of Transportation, December 2016.
http://www.udot.utah.gov/main/uconowner.gf?n=34265018898672851
This report provides an overview of several data collection methodologies commonly used by

state DOTs and discusses LiDAR and its capabilities and limitations in greater detail. The report also offers a comparison of the different types of LiDAR (airborne, mobile and terrestrial), and the advantages and disadvantages of each.

Geospatial 3D As-Found Surveys: A Key Component of Utah's Integrated Asset Management Program, *Program Case Study: 3D Engineered Models: Schedule, Cost and Post-Construction*, Every Day Counts, Federal Highway Administration, 2015.
https://www.fhwa.dot.gov/construction/3d/hif15023.pdf
From the introduction:

> UDOT's [Utah DOT's] vision for asset management is a cradle-to-cradle approach where asset information requirements in each phase of project delivery drive the way asset data is collected and used, leading to efficient business plans and truly lean asset management. Through cross-divisional synergies and leveraging parallel departmental initiatives, UDOT ultimately initiated an asset data collection program that is organically evolving into the first fully integrated asset management system in the United States, one that is producing results in the form of cost savings and process efficiencies.

This publication describes elements of Utah DOT's asset management program:

- UPlan is a web-based GIS platform that allows internal and external users to easily customize and share maps of geospatially located data.
- UGate is the agency's central GIS data repository. UGate pulls data from many different UDOT databases that the divisions then access through portals.
- Linear Bench, developed with consultant assistance, is a straight-line diagram application that complements UPlan in specific cases where there are so many assets in place that a map does not properly communicate the relationship between them (e.g., assets in a roadway).
- Esri's Open Data provides easy and transparent access to all public UDOT data in multiple formats, not just in GIS format as UPlan does.

Utah DOT Leveraging LiDAR for Asset Management Leap, Phil Ellsworth, Utah Department of Transportation, 2013.
https://www.udot.utah.gov/main/uconowner.gf?n=8336606666333974
From the introduction: In a world where LiDAR has revolutionized movie making, the Utah Department of Transportation is employing this impressive technology on a groundbreaking data collection project that will set the stage for vastly improved asset management—not just at UDOT, but across the country. After advertising a one-of-a-kind Request for Proposals (RFP) in the fall of 2011, UDOT has recently entered into a contract with Mandli Communications to gather, identify and process a wide variety of roadway assets along its entire 6,000+ center lane miles of [s]tate [r]outes and [i]nterstates. With the winning bidder (Mandli) proposing to use mobile LiDAR as its primary technology on the project (along with an array of other sensors), this UDOT contract may very well be the first of its kind in technological magnitude and scope.

Asset Data Management

Additional aspects of agencies' asset data management programs were discussed, including:

- Staff access to data.
- Asset data migration and storage.
- Asset data delivery format.

Staff Access to Data

Data Products

Respondents from 11 agencies described the products from the data collection and extraction efforts that are made available to staff, including extracted assets, imagery and point cloud data. All agencies make extracted assets available to staff, and all except Minnesota DOT make imagery available. The Minnesota DOT respondent noted that imagery and point cloud data are available to staff by special request. Point cloud data is available to staff in seven states: Alabama, Hawaii, Iowa, Mississippi, North Carolina, Utah and Virginia.

In addition to these products, Mississippi DOT provides PMS data to staff, and New Hampshire DOT provides GIS data. Hawaii DOT asset data is available through the agency's Roadview Explorer application (see page 18 for information about this application). Utah DOT makes data available through UPlan, "a web-based GIS platform that allows internal and external users to easily customize and share maps of geospatially located data." Table 8 summarizes survey responses.

Table 8. Data Products Available to Staff

State	Extracted Assets	Imagery	Point Cloud	Other	Description
Alabama	X	X	X		N/A
Hawaii	X	X	X	X	Data available through Roadview Explorer application.
Iowa	X	X	X		N/A
Kansas	X	X			N/A
Minnesota	X			X	Imagery and point cloud data available by special request.
Mississippi	X	X	X	X	PMS data.
New Hampshire	X	X		X	GIS.
New York	X	X			N/A
North Carolina DPS	X	X	X		N/A
Utah	X	X	X	X	Data available through Utah DOT UPlan web site.
Virginia	X	X	X		N/A
Total	**11**	**10**	**7**	**5**	

Data Distribution Methods

A range of methods are used by respondents to make asset data available to staff, including:

- Agency-hosted web-based application.
- Consultant-hosted web-based application.
- Enterprise data warehouse.
- Multiple data marts.
- On-premise file server.
- Separate databases.
- Separate geodatabases.
- Web services.

Nine agencies (all except Alabama DOT and North Carolina DPS) use an agency-hosted web application to make asset data available to staff, and all except Alabama and Kansas DOTs and North Carolina DPS use enterprise data warehouses. Only two state DOTs use consultant-hosted web applications (Hawaii and Iowa) or multiple data marts (Hawaii and Virginia).

Less frequently used methods are separate databases (Hawaii, Minnesota, Mississippi, New Hampshire and Virginia); web services (Hawaii, Iowa, Minnesota, New York and Virginia); and separate geodatabases (Hawaii, Minnesota, New Hampshire and Virginia).

The respondent from North Carolina DPS reported that asset data is made available through North Carolina DOT. The New Hampshire DOT respondent noted that putting legacy systems like bridge management data in one location is "still a work in progress." Table 9 summarizes survey responses.

Table 9. Methods Used to Share Asset Data With Staff

State	Agency Hosted Web App	Consultant Hosted Web App	Data Ware house	Multiple Data Marts	On Premise File Server	Separate Databases	Separate Geo databases	Web Services	Other
Alabama					X				
Hawaii	X	X	X	X	X	X	X	X	
Iowa	X	X	X					X	
Kansas	X								
Minnesota	X		X		X	X	X	X	
Mississippi	X		X		X	X			
New Hampshire	X		X		X	X	X		
New York	X		X					X	
North Carolina DPS									X[1]
Utah	X		X						X[2]
Virginia	X		X	X	X	X	X	X	
Total	**9**	**2**	**8**	**2**	**6**	**5**	**4**	**5**	

1 Through North Carolina DOT.

2 Available through Utah DOT UPlan site.

Asset Data Migration and Storage

Asset data is migrated from mobile or other collection practices to storage through various mechanisms, primarily web services but also through contractors and paper or manual practices. Some state agencies participating in the survey, such as Kansas and Minnesota DOTs, use multiple processes, depending on the asset. For example, one collection vehicle in Kansas gathers pavement data that is migrated through solid-state drives; state-owned bridge data is collected on paper and entered into a bridge management system at agency headquarters; data for locally owned bridges is entered via a web portal. Survey responses are summarized below by practice:

Web Services

- *Alabama*. All non-LiDAR inventories or asset collection is migrated using web services that are synced daily to features within an Alabama ArcGIS portal. LiDAR data is moved from a unit via hard drives for processing and then stored within an on-site file server.
- *Iowa*. Asset data is stored in a portal.
- *Kansas*. Collection vehicle gathers pavement data that is transferred to storage through solid-state drives.
- *Minnesota*:
    - Pavement. An annual pavement survey/van is a standalone process.
    - Roadside assets. Much of this data, if it is collected or updated manually, is managed through GIS apps that sync with the agency's transportation asset management system (TAMS) (AgileAssets).
- *New Hampshire*. Mobile data collection is migrated primarily with iPads to the Esri cloud and to the agency's GIS.

Contractor

- *Hawaii*. The data collection contractor submits all deliverables to Hawaii DOT, and data is ingested into the agency's enterprise system.

Mobile and Paper Processes

- *Kansas*:
    - State-owned bridges. Data is collected on paper and then entered into a bridge management system at agency headquarters.
    - Locally owned bridges. Data is entered via a web portal.

Other

- *North Carolina DPS*: Data is stored and provided by the key stakeholder.
- *Utah*. The agency is currently procuring a new maintenance/asset management system for this process.

Asset Data Delivery Format

Respondents from 11 agencies described how data from agencies' statewide asset collection effort is delivered:

- Vendor proprietary format, although a perpetual license is provided to the state.
- Standard format that is open to a third party, allowing full access of the data.
- Other format.

Alabama DOT is the only agency that uses a vendor proprietary format. Five agencies—Iowa, Kansas, New York and Utah DOTs and North Carolina DPS—use a standard format. The North Carolina DPS respondent added that agency data is available via a web site and is provided to North Carolina DOT.

Agencies in two states—Hawaii and Virginia—use both a vendor proprietary and standard format. The Hawaii DOT respondent added that depending on the sensor (such as LiDAR) and data, the agency uses a combination of both proprietary and standard formats with access via REST services to third parties. Table 10 summarizes survey results.

Table 10. Format for Delivering Asset Data

State	Vendor Format	Standard Format	Other	Description
Alabama	X			N/A
Hawaii			X	• Combination of proprietary and standard formats, depending on the sensor (such as LiDAR) and data. • Access via REST services to third parties.
Iowa		X		N/A
Kansas		X		N/A
Minnesota			X	Format specific to agency TAMS asset attribution parameters, since it is the source of record for most nonpavement/bridge data.
Mississippi			X	• Format specified in HPMS and PMS, depending on the asset. • Typically Access databases and/or CSV files.
New Hampshire			X	• *Externally*: Some data available through GIS services, other tabular downloads. • *Internally*: More data available through native systems, databases, data warehouse, GIS, etc.
New York		X		N/A
North Carolina DPS		X		Data available via a web site and is provided to North Carolina DOT.
Utah		X		N/A
Virginia			X	Vendor proprietary and standard formats.
Total	**1**	**5**	**5**	

Assessment of Agency Practices

Benefits of a Coordinated Approach

Respondents from 11 agencies indicated that their agencies' operations were enhanced as a result of implementing a coordinated statewide asset data collection and management strategy. The New York State DOT respondent noted that since implementation had only begun, the value of this approach is not yet well understood. The Virginia DOT respondent said that the data collection process has led the agency to develop a needs-based maintenance and operations program budget since 2006. In 2017, the Commonwealth of Virginia's General Assembly provided additional funding for pavements and bridges, which began with presented needs from the data collected.

The key benefits reported by nine respondents were:

- Improved performance.
- Streamlined resources.
- Comprehensive view of assets.
- Opportunities for increased funding.

Table 11 summarizes survey responses.

Table 11. Benefits of a Coordinated Asset Data Collection and Management Strategy

Topic	State	Description

Improved Performance	Alabama, Kansas, New Hampshire, North Carolina DPS, Utah	• *Alabama*. Extracted data more easily leveraged by enterprise systems.
		• *Kansas*. State is nationally recognized for its pavement quality.
		• *New Hampshire*:
		  ○ Moving most roadside collection to iPads and Esri cloud facilitates standardization and makes upkeep easier.
		  ○ Governance structure and central coordination help ensure data maintenance.
		• *North Carolina DPS*. Statewide high-density LiDAR.
		• *Utah*. Time and data alignment.

Streamlined Resources	Iowa, Minnesota, Mississippi	• *Iowa*. Less duplication of collection and storage. • *Minnesota*. Unifying approach and quality contract management among districts allow for statewide stakeholder collaboration, which leads to economies of scale. • *Mississippi*. Using the same contract for HPMS and PMS reduces duplication/mobilization costs and time.
Comprehensive View of Assets	Kansas	Issues with certain construction types more apparent.
Increased Funding	Virginia	In 2017, additional funding for pavements and bridges from state's General Assembly.

Challenges with a Coordinated Approach

According to the 11 respondents, implementing a statewide asset data collection and management approach was not without its challenges.

The primary challenges reported by respondents were:

- Enterprise-level coordination.
- Differing data needs among stakeholders.
- Resources, including costs and staffing.

Table 12 summarizes survey responses.

Table 12. Challenges With a Coordinated Asset Data Collection and Management Strategy

Topic	State	Description
Enterprise-Level Coordination	Alabama, Iowa, Minnesota, New Hampshire, Utah	*Alabama*. Difficulty managing and organizing large data sets. *Minnesota*. Variance in districts' legacy data. *New Hampshire*. Coordination takes time. One group wants to collect data quickly for its purpose only. *Utah*. Pulling information from a number of systems to obtain a comprehensive look at all agency assets.

Topic	State	Description
Differing Data Needs	Minnesota, Mississippi, North Carolina DPS	*Minnesota*. Variable buy-in for the need for asset data. *Mississippi*. Different segmentation of roadways. *North Carolina DPS*. Determining the needs and requirements of all end user agencies.
Resources (Cost, Staff)	Hawaii, Minnesota, New Hampshire, Virginia	*Hawaii*. Getting all staff up to speed. *Minnesota*. Competition for resources to collect and manage data versus deliver programs. *New Hampshire*. Only able to accommodate a limited number of ongoing collection efforts. *Virginia*. Expense: $38 million annually for bridge inspection data collection alone (consultants and in-house staff).
Other	Minnesota, New York	*Minnesota:* • Variable technologies and platforms among districts. • Capturing as-constructed data. *New York*. Writing a specification to update asset data from construction projects.

Recommendations for Implementation

Nine agencies provided recommendations for other agencies developing a coordinated statewide program to collect and manage asset data. Most recommendations encouraged:

- Beginning with a strong foundation and consistent framework.
- Establishing governance and coordination among stakeholders.
- Communicating to illustrate the benefits of this approach and to work through any challenges.

Table 13 summarizes survey responses.

Table 13. Recommendations for Implementing a Coordinated Approach to Asset Data Collection

Topic	State	Description
Strong Foundation and Consistent Framework	Hawaii, Iowa, Minnesota, New Hampshire, Utah, Virginia	*Hawaii*. Build on existing programs and technologies and practices. *Iowa*: • Begin with a solid core network geodatabase repository. • Establish strong requirements or standards. *Minnesota*: Build processes and consent prior to data collection. *New Hampshire*: Create a plan and commit resources to data maintenance. *Utah*: • Develop a well-defined list of attributes and data formats that agency needs to collect. • Determine how agency will store data and frequency of data collection.

Topic	State	Description
Strong Foundation and Consistent Framework	Hawaii, Iowa, Minnesota, New Hampshire, Utah, Virginia	*Virginia*: • Use best practices from other states. • Engage outside assistance to set up a uniform process. • Start with one or two assets (data collection is costly).
Governance and Coordination	Alabama, Iowa, Minnesota, New Hampshire, North Carolina DPS, Utah	*Alabama*: • Include stakeholders from outside central office on advisory committees. • Consider organizational structure: current staff's ability to extract collected data. *Iowa*. Include all enterprisewide participants. *Minnesota*: Have a dedicated team with broad expertise. *New Hampshire*. Coordinate to avoid collection duplication. *Utah*: Create a single focal point who manages the program and works with all critical asset champions.
Communication	Minnesota, Mississippi	*Minnesota*: Communicate needs/benefits of data. *Mississippi*. Communicate and work through challenges.
Other	Mississippi	*Mississippi*. Linear referencing important.

Note: The Utah DOT respondent recommended contacting Adam Radel and Scott Jones of Utah DOT for more information about developing a coordinated statewide program for asset data collection and management:

Scott Jones
Director of Data, Technology and Analytics
Utah Department of Transportation
801-965-4140, wsjones@utah.gov

Adam Radel
Department of Technology Services
Utah Department of Transportation
801-427-0808, at aradel@utah.gov

Related Research and Resources

A literature search of recent publicly available resources identified publications that are organized into two topic areas:

- National guidance.
- State research and practices.

National Guidance

Citations are organized into the following topic areas:

- Data collection and management.
- Remote and mobile data collection.

Data Collection and Management

Project in Progress: NCHRP 08-115: Guidebook for Data and Information Systems for Transportation Asset Management, start date: August 2018; expected completion date: October 2019. (The TRB web site indicates that this project is currently "Active"; no final deliverables appear to be publicly available.)
https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4362
From the objective: The objective of this research is to develop a guidebook presenting principles, organizational strategies, governance mechanisms and practical examples for improving management of the processes for collecting data, developing useful information, and providing that information for decision making about management of the transportation system assets.

Data Governance and Data Management: Case Studies of Select Transportation Agencies, Michael Green and Anthony Lucivero, *GIS in Transportation*, Federal Highway Administration, July 2018.
https://www.gis.fhwa.dot.gov/documents/GIS_Data_Governance_and_Data_Management_Case_Studies.pdf
This report provides examples of how state DOTs "currently define the concepts of 'data governance' and 'data management,' and the formal or informal policies used to implement them within a context of geographic information systems (GIS)." Case studies were developed using feedback from four state DOTs—Arizona, Arkansas, Ohio and Texas. Lessons learned begin on page 13 and include:

- Without a governing body, implementing data governance is very difficult.
- Data governance and data management have a symbiotic relationship.
- A GIS-specific capability maturity model (GIS-CMM) would benefit state DOTs.

"Assessing the Maturity of Transportation Data Management Practices Based on a Survey of State DOTs," Isaac C. Oti and Nasir G. Gharaibeh, *Transportation Research Board 97th Annual Meeting*, Paper #18-01301, January 2018.
Citation at https://trid.trb.org/view/1494834
From the abstract: This paper provides a quantitative assessment of the maturity of data stewardship, storage and warehousing, and integration practices for 16 transportation data groups based [on] a survey of 33 [to] 43 state DOTs. …The assessment results show that data management practice at the system monitoring and operations phases are likely to be more mature than other data groups. Roadway inventory data, in particular, seem to be significantly

ahead. On the other end, real estate data and travel modeling data have the least mature data management practices. A comparison of the data management practices indicates that data stewardship is more mature than data integration, storage and warehousing practices. It is hoped that this assessment will help transportation agencies to optimize efforts to achieve sound agency-wide data management practices.

NCHRP Synthesis 508: Data Management and Governance Practices, Nasir Gharaibeh, Isaac Oti, David Schrank and Johanna Zmud, 2017.
Publication available at https://www.nap.edu/catalog/24777/data-management-and-governance-practices
From the abstract:

> This synthesis provides information on current practices in data governance, data warehousing and cloud computing, data integration and sharing, and data quality assurance. The objective was to develop a collection of transportation agency data management practices and experiences. The information in this synthesis was gathered through a literature review, a two-phase online survey and follow-up interviews with four agencies. The report demonstrates how agencies currently access, manage, use and share data.

The following is a sampling of the conclusions appearing in Chapter 6, Conclusions and Future Research, beginning on page 37 of the report (page 44 of the PDF):

- *Data governance*. In most cases, DOTs have data stewards and data coordinators for managing individual data sets and coordinating data management within a business area (e.g., asset management, safety). What is lacking, in most cases, is a data governance council/board for policy making and coordination at the enterprise level.
- *Data warehousing and cloud computing*. Although there is a general agreement in the literature that transportation agencies collect and manage large amounts of data, most DOTs and local agencies do not have reliable estimates of the amount of data they maintain.
- *Data integration and sharing*. An area prime for reducing the duplication of data within DOTs is the creation of digital as-builts from 3-D models used in design and construction. However, the integration of these as-builts into legacy data management systems is challenging, in part because of the inherent limitations of legacy systems (e.g., some legacy systems do not use georeferenced data) and broader institutional issues (e.g., data owned/managed by different parts of the agency).
- *Data quality*. For DOTs, timeliness, accuracy and access security are most commonly evaluated. Conversely, consistency is the data quality dimension least evaluated by DOTs.

A Guide to Collecting, Processing and Managing Roadway Asset Inventory Data, NCHRP Project 20-07/Task 357, Kathryn A. Zimmerman and Kartik Manda, June 2015.
http://sp.maintenance.transportation.org/Documents/NCHRP%2020-07_task%20357%20A%20Guide%20to%20Collecting,%20Processing,%20and%20Managing%20Roadway%20Asset%20Inventory%20Data.pdf
From the abstract: This project was initiated by the National Cooperative Highway Research Program to develop guidance for establishing and managing roadway asset inventories. The resulting Guide, which was written as a stand[-]alone document, can be used by transportation agencies to help make informed decisions on the type of technology most appropriate for collecting asset inventory information and the considerations that must be taken into account for

processing and managing the data. The study concentrated on both manual and automated data collection approaches, including manual surveys, photogrammetric methods and remote sensing technology (e.g., mobile LiDAR).

The Guide includes considerations that should be evaluated during all phases of establishing or updating an asset inventory. First, the Guide addresses technical considerations that should be taken into account regardless of the data collection selected, such as developing criteria for classifying assets and developing data collection standards. Secondly, the Guide presents factors to consider in determining the appropriateness of each of the three technologies used in collecting inventory data. This section includes factors such as the level of accuracy required and the visibility of the asset from the road. Next, the Guide includes considerations for collecting the data, including differences depending on whether the data will be collected using in-house personnel or an outside contractor. Finally, the Guide suggests considerations for managing the data effectively, including topics such as storage requirements and update schedules.

RDIP Technical Assistance: Roadway Safety Data Program, Federal Highway Administration, undated.
https://safety.fhwa.dot.gov/rsdp/rdip.aspx
From the web site: The Roadway Data Improvement Program (RDIP) focuses on helping with an agency's process and practices for collecting, managing and utilizing their roadway data. Technical assistance can help your agency improve data collection across these key areas:

1. Roadway Data Collection and Technical Standards
2. Data Analysis Tools and Uses
3. Data Management and Governance
4. Data Sharing and Integration

A technical assistance team provided by the RDIP reviews and assesses a state's roadway data system for the content of the data collected, ability to use, manage and share the data and to offer recommendations for improving the roadway data. The RDIP also examines the [s]tate's ability to coordinate and exchange roadway data with local agencies such as cities, counties and MPOs [metropolitan planning organizations]. The RDIP is ultimately intended to help states improve the roadway data the [s]tate uses to develop their Strategic Highway Safety Plan (SHSP), which supports the State's Highway Safety Improvement Program (HSIP).

Feasibility of a Model Inventory of Roadway Elements, *MIRE MIS: MIRE Management Information System*, Federal Highway Administration Safety Program, 2013.
https://safety.fhwa.dot.gov/rsdp/downloads/feasibility.pdf
This document describes the Model Inventory of Roadway Elements (MIRE) Management Information System (MIS) project that tested the feasibility of converting the MIRE listing and data dictionary of roadway and traffic data elements into an MIS. As the introduction notes, "FHWA developed MIRE as a recommended listing and data dictionary of roadway and traffic data elements critical to supporting highway safety management programs and tools. MIRE consists of 202 roadway and traffic data elements grouped under three major categories: 1) roadway segments, 2) roadway alignments, and 3) roadway junctions." The project team examined mechanisms for data collection; processes for data handling and storage; details of data file structure; methods to assure the integration of MIRE data with crash data and other data types; and performance measures to assess and assure MIRE data quality and MIS performance.

Related Resources:

"RIDOT's Statewide Roadway and Asset Data Collection Project," Rafiq Basaria, Daniel Behnke and Shane White, Rhode Island Department of Transportation, *Esri User Conference*, 2017.
http://proceedings.esri.com/library/userconf/proc17/papers/533_125.pdf
This presentation discusses Rhode Island DOT's efforts to collect and manage asset data, including:

- Data integration through Esri Roads and Highways implementation.
- Conversion from multiple linear referencing systems.
- Supporting bidirectional data flow and consistent location referencing across business systems.
- Developing processes and identifying staffing and resources needed to guarantee the ongoing maintenance and utility of the roadway location and MIRE inventory data.
- Managing data integration and assisting the agency in developing processes for integration of the new MIRE data into Esri Roads and Highways.

"Adding MIRE Attribution to the Enterprise Network Asset Data Model," Greg Ciparelli (Connecticut Department of Transportation) and Marc Kratzschmar (Bentley Systems), March 2018.
https://gis-t.transportation.org/wp-content/uploads/sites/51/2018/05/Adding-MIRE-Items-to-the-Enterprise-Network-Asset-Data-Model_Final_2018_03_21.pdf
This presentation discusses how Connecticut DOT has incorporated the use of MIRE into its asset data collection and integration efforts.

Remote and Mobile Data Collection

Mobile Applications for GIS: Case Studies of Select Transportation Agencies, Drew Quinton and Anthony Lucivero, *GIS in Transportation*, Federal Highway Administration, February 2019.
https://www.gis.fhwa.dot.gov/case_studies/Mobile_Applications_for_GIS_Case_Studies.pdf
This report presents case studies of five state transportation agencies "that have demonstrated experience in the field leveraging mobile application technology" to collect and manage geospatial asset data—Colorado, Kansas, Kentucky, Maryland and Missouri. The report's conclusion notes that "following in the footsteps of the agencies interviewed for this study should provide a practical basis on knowledge from which to begin the implementation process."

GIS and Data Governance Peer Exchange Summary Report, Federal Highway Administration, 2018.
https://www.gis.fhwa.dot.gov/reports/GIS_and_Data_Governance_Peer_Exchange_ARDOT.pdf
This peer exchange included presentations from representatives of six DOTs—Arkansas, Connecticut, Iowa, Ohio, Michigan and Tennessee. Roundtable discussions included the following topics:

Data Governance Policy

- Data catalogues can show how the data can be used, how it can be queried and who to contact about it.

- Databases should be unable to be duplicated, and centrally located.
- Putting legacy applications into a database viewer to be visualized can be a useful solution.

Technical Tools for Data Governance

- *Data access, collection and storage*. Controlling access to data is a necessary step toward data governance. Agencies can have multiple data warehouses or servers, but it is necessary to minimize the number of data formats, tools and architectures to eliminate duplication of function and reduce the complexity of the overall system.
- *Valuing data and making investments*. The level of accuracy and detail required in data should be dictated by the importance of the data to an agency's work, which should subsequently influence the direction of data governance efforts.
- *Funding*. Agencies should seek to justify funding of data governance by looking at how much money is routinely spent on cleaning data.
- *Communication materials*. Internal documents can be designed to serve multiple communications goals. Among these documents are introductory-level materials to help familiarize staff with data governance and technical information to assist in completing and operationalizing data governance processes and procedures.
- *Starting the data governance process*. The first step toward data governance should be conducting a capability maturity model (CMM)-style assessment with data owners and users. These staff members need to be well versed in GIS, but also open to change and hearing negative feedback.

Data Governance Staffing and Strategy

- Agencies may need to create a new job series, new positions in their current structure, or new staff with an IT background. The challenges of having mixed departments make it difficult to supervise GIS work when managers do not have that background.
- Agencies need formalized staff in positions where they can take charge of data governance and data quality assurance/quality control.

Related Resource:

"Data Governance and Data Management: State Examples," *2019 AASHTO GIS-T Symposium*, April 2019.
https://gis-t.transportation.org/wp-content/uploads/sites/51/2019/04/GIS-and-Data-Governance-Peer-Exchange-GIST2019.pdf
This presentation presents highlights of the peer exchange cited above and other FHWA activities related to data governance, including brief descriptions of how states are engaging in the areas of data governance and data management.

NCHRP Report 748: Guidelines for the Use of Mobile LIDAR in Transportation Applications, Michael J. Olsen, Gene V. Roe, Craig Glennie, Fred Persi, Marcus Reedy, David Hurwitz, Keith Williams, Halston Tuss, Anthony Squellati and Michael Knodler, 2013.
Publication available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_748.pdf
From the foreword: The objective of the project was to develop guidelines for the use of mobile LIDAR technology in transportation applications. The guidelines (1) are based on an analysis of current and emerging applications in areas such as project planning, project development, construction, operations, maintenance, safety, research and asset management; (2) address

data collection methods, formatting and management, storage requirements, quality assurance, and the translation and formatting of derived products; and (3) are based on and organized around performance criteria such as data precision, local (relative) accuracy, network (absolute) accuracy and point density.

….

The guidelines are organized into two parts. Part 1: Management and Decision Making provides guidance on the use and integration of mobile LIDAR data for a wide range of transportation applications without requiring in-depth knowledge of the technology; Part 2: Technical Considerations provides the details needed to completely specify the project requirements and appropriate deliverables.

State Research and Practices

Citations are organized into the following topic areas and by state within each topic:

- Data collection and management.
- Remote and mobile data collection.
- Use of imaging.
- Use of intelligent transportation systems.
- Use of LiDAR.

Data Collection and Management

Multiple States

TRB Webinar: Practical Technology-Based Approaches to Highway Infrastructure Maintenance, Colorado Department of Transportation, Utah Department of Transportation and Texas Transportation Institute, April 2017.
http://onlinepubs.trb.org/onlinepubs/webinars/170412.pdf
This webinar includes two presentations that are relevant to asset data collection and management. The webinar begins with a presentation by Colorado DOT that examines how the agency is collecting data and the data it collects, and how the agency is expanding data beyond a simple inventory. The third presentation, "Evaluation of Emerging Technologies for Safety and Operations Infrastructure Inventory and Condition Assessment" by Texas Transportation Institute, begins on slide 70 and addresses Texas DOT's examination of mobile high-speed data collection.

Connecticut

"Connecticut DOT: Data Management for Asset Management," William S. Pratt and Karen M. Riemer, *11th National Conference on Transportation Asset Management*, July 2016.
http://onlinepubs.trb.org/onlinepubs/conferences/2016/AssetMgt/73.FrancesHarrison.pdf
This presentation discusses Connecticut DOT's development of a transportation asset management plan, current asset inventory systems, identifying and harvesting assets, and the state's Asset and Project Data Gap Assessment and Implementation Plan.

Florida

RCI Features and Characteristics Handbook, Florida Department of Transportation, August 2016.
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/statistics/rci/rcifchandbook.pdf?sfvrsn=bac2fc94_2
From the introduction: This handbook identifies and defines the data found in the Roadway Characteristics Inventory (RCI). This handbook also provides basic guidelines and considerations to assist the RCI data collector. The features and characteristics in RCI reflect the roadway data of interest to the Florida Department of Transportation.

Illinois

Investigation of Methods and Approaches for Collecting and Recording Highway Inventory Data, Huaguo Zhou, Mohammad Jalayer, Jie Gong, Shunfu Hu and Mark Grinter, Illinois Department of Transportation, June 2013.
https://pdfs.semanticscholar.org/2841/5cf16baa003dc5f4dd7ab8a1b8d60eca70c0.pdf
From the abstract: This research project sought to determine cost-effective methods to collect highway inventory data not currently stored in IDOT [Illinois DOT] databases for implementing the recently published Highway Safety Manual (HSM). The highway inventory data collected using the identified methods can also be used for other functions within the Bureau of Safety Engineering, other IDOT offices or local agencies. A thorough literature review was conducted to summarize the available techniques, costs, benefits, logistics and other issues associated with all relevant methods of collecting, analyzing, storing, retrieving and viewing the relevant data.

Related Resource:

"A Comprehensive Assessment of Highway Inventory Data Collection Methods," Mohammad Jalayer, Huaguo Zhou, Jie Gong, ShunFu Hu and Mark Grinter, *Journal of the Transportation Research Forum*, Vol. 53, Issue 2, pages 73-92, Summer 2014.
https://pdfs.semanticscholar.org/b250/4018d2bb7258421943b40361db49c9f55d28.pdf
From the abstract:

> The focus of this study is to characterize the capability of existing methods for collecting highway inventory data vital to the implementation of the recently published HSM [Highway Safety Manual]. More specifically, this study evaluated existing highway inventory methods through a nationwide survey and a field trial of identified promising highway inventory data collection (HIDC) methods on various types of highway segments. A comparative analysis was conducted to present an example [of] how to incorporate weights provided by state DOT stakeholders to select the most suitable HIDC method for the specific purpose.

Conclusions and recommendations begin on page 88 of the article (page 17 of the PDF) and include:

- The GPS data logger method can be employed for short distances, low speeds, and low to medium traffic volume roadways that are not obstructed by buildings or trees.
- Robotic total station technology can be employed for points of specific interest, such as intersections.
- The photo/video log method, together with high-resolution aerial imagery, can be used to collect roadside inventory data for large-scale statewide data collection.
- Mobile LiDAR technology can be utilized to gather highway inventory data with the

highest data quality and completeness for serving multiple offices in state DOTs and local agencies. In order to share the costs of the mobile LiDAR data collection and processing, identifying multiple clients within the DOT is important.

Indiana

A Synthesis Study on Collecting, Managing and Sharing Road Construction Asset Data, Hubo Cai, Chenxi Yuan, Timothy B. McClure and Phillip S. Dunston, Indiana Department of Transportation, September 2015.
https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=3110&context=jtrp
From the abstract:

> The purpose of this project was to conduct a synthesis study to 1) assess the current status at INDOT [Indiana DOT] regarding the collection of asset data during the construction phase and the use of such data in the operation and maintenance (O&M) phase, and 2) develop a framework for INDOT to leverage the construction inspection and documentation process to collect data for assets. Data needs during O&M were identified through rounds of meetings with relevant INDOT business units. The current practice in construction documentation was investigated in detail. A survey of state highway agencies (SHAs) was conducted to assess the state-of-the-practice.

The report's recommendations for implementation begin on page 38 of the report (page 47 of the PDF) and include the following:

- Replace paper-based format with electronic files—electronic design files are passed on to construction engineers; electronic files are marked, modified and commented during the construction phase to reflect the as-constructed and as-built condition.
- Use the data needs assessment framework (Figure 5.1 in Section 5.1.2) to identify the data needs from INDOT business groups for all infrastructure assets to create a comprehensive view of what data items are needed by which business groups. The result forms the base for guiding the flow of asset data collected during construction into relevant asset management information systems and maintaining the data integrity across all information management systems in INDOT.
- Retain the association between plan assets and pay items as a part of the design documents to be included in the contract documents. The one-to-one relationship between a plan asset and a pay item allows bringing relevant information to construction engineers in real time.
- Adopt the guideline, especially its mapping mechanism, in the mobile construction documentation app. As illustrated in Section 5.6.4, the mapping mechanism integrates the collection of asset data items into the construction documentation process and the guideline enables the flow of these asset data items collected during the construction documentation process into suitable places in the corresponding asset management information systems.

Ohio

Development of Transportation Asset Management Decision Support Tools, Eddie Chou, Ohio Department of Transportation, August 2017.
https://rosap.ntl.bts.gov/view/dot/32802
From the abstract: This study developed a web-based prototype decision support platform to demonstrate the benefits of transportation asset management in monitoring asset performance, supporting asset funding decisions, planning budget tradeoffs and optimizing resource

allocations. … A centralized transportation asset database that integrates data from various sources was built to support the data-driven decision support tools. This allows reports/presentations to be generated quickly and enables what-if analyses to be performed. A total of 23 functions were developed in five categories: inventory, condition, performance, investment and planning. The tradeoff analysis function is developed for evaluating funding levels versus performance and cross-asset budget allocation decisions.

Oregon

Asset Management in Oregon: Roadway Safety Data and Analysis Case Study, Richard Brown, Federal Highway Administration Office of Safety, November 2016.
https://safety.fhwa.dot.gov/rsdp/downloads/fhwasa16110.pdf
From the abstract: Over several years, ODOT [Oregon DOT] implemented two new programs to manage their roadway assets, TransInfo and the Features, Attributes and Conditions [Survey]—Statewide Transportation Improvement Program (FACS-STIP) Tool. TransInfo is a statewide asset management system. It provides ODOT asset management staff with the most up-to-date statistics on assets and other features on the State highway system. The FACS-STIP Tool is a web-based program that provides information on an asset's location, attributes and condition to all users with internet access.

Remote and Mobile Data Collection

Michigan

Monitoring Highway Assets With Remote Technology, Dye Management Group, Inc., Michigan Department of Transportation, July 2014.
https://www.michigan.gov/documents/mdot/RC-1607_466453_7.pdf
From the abstract:

> The purpose of this research was to evaluate the benefits and costs of various remote sensing technology options and compare them to the currently used manual data collection alternative. The DMG's [Dye Management Group, Inc., the report's author] evaluation was used to determine how useful and feasible it would be to perform inventory collection of the Michigan Department of Transportation's (MDOT's) twenty-seven high/medium priority assets. DMG performed a pilot project, using several selected routes in MDOT's Southwest Region, to evaluate different remote technologies and to provide recommendations for how best to implement the most viable of these technologies as data collection tools and data centralization methods.

Results and recommendations include:

- Remote technologies are capable of gathering highway asset data on most MDOT assets. Notable exceptions include assets not readily visible from the roadway (e.g.[,] culverts).
- LiDAR technology, while useful in the appropriate application, produces a level of detail beyond that necessary for the assets identified under this study and was not considered a cost-effective alternative.
- Mobile imaging technology offers an opportunity to effectively gather highway asset data while decreasing worker exposure to traffic, increasing data accuracy and quality, speeding data collection, and reducing overall costs relative to manual data collection methods.
- DMG recommends that MDOT outsource data collection using mobile imaging technology to a vendor that can handle a project of this magnitude.

Use of Imaging

Georgia

Exploration of Using GDOT's Existing Videolog Images and Pavement Surface Imaging Data to Support Statewide Maintenance Practices, Zhaohua Wang and Yichang (James) Tsai, Georgia Department of Transportation, April 2016.
http://g92018.eos-intl.net/eLibSQL14_G92018_Documents/14-22.pdf
From the abstract: To maximize the return on investment, GDOT is seeking to utilize the existing videolog and pavement imaging data for extracting roadway asset data that is indispensable for supporting the statewide asset management and maintenance programs. For this purpose, this research project explored the utilization of GDOT's existing videolog and pavement imaging data for extracting guardrails, rumble strips and traffic signs. Image-processing-based algorithms were developed, which were tested using both GDOT's videolog images and the data collected by using the Georgia Tech Sensing Vehicle (GTSV).

Use of Intelligent Transportation Systems

Michigan

Management Procedures for Data Collected Via Intelligent Transportation Systems, Qiang Hong, Richard Wallace, Brian Reed, Anthony Gasiorowski and Eric Paul Dennis, Michigan Department of Transportation, July 2015.
http://www.cargroup.org/wp-content/uploads/2017/02/MANAGEMENT-PROCEDURES-FOR-DATA-COLLECTED-VIA-INTELLIGENT-TRANSPORTATION-SYSTEMS.pdf
This report "summarizes and discusses state-of-the-industry and best practices, national ITS research programs and their implications, and existing MDOT [Michigan DOT] plans and data systems." The following are brief excerpts from Chapter 7, Conclusions and Recommendations, beginning on page 29 of this report (page 37 of the PDF):

- Develop a statewide master/strategic plan for database aggregation across ITS subsystems and programs.
- Each information model (GIS, TAMS, ITS, etc.) should contain best practices for database schema design and integration, leveraging a core geospatially enabled and accurate basemap (centerline and cadastral data layers), which are effectively maintained through the MGF [Michigan Geographic Framework].
- Statewide Light Detection and Ranging (LIDAR) and Orthophoto data sets should be collected on an annual or semiannual basis. Once the data are collected, they should be integrated with the baseline GIS data model within the data warehouse.
- Data aggregation should be undertaken in a series of phases by ITS subsystems and performed based on prioritization of the data sets. Based on the initial projections, the hardware and database type required to perform under this load condition would most likely be Oracle or DB2 running on dedicated application hardware with a separate storage platform/architecture.
- Data aggregation would be best served by integrating real-time data (one per minute or one per five-minute intervals) from key ITS subsystems, with a retention period of 45 days being represented as current data.
- After 12 months, data should be moved on an annual basis to secondary storage disks to allow for rapid access but represented as archival. This would allow for longer-term business analytics and metrics analysis/trending.
- The enterprise data warehouse would best be geographically dispersed within the [s]tate as regional nodes within a Database Management System (DBMS) High Availability (HA) Cluster.

Use of LiDAR

Multiple States

Project in Progress: Uses and Challenges of Collecting LiDAR Data From a Growing Autonomous Vehicle Fleet: Implications for Infrastructure Planning and Inspection Practices, Mountain-Plains Consortium, start date: October 2018; expected completion date: July 2022.
Full project description at https://www.mountain-plains.org/research/downloads/2018-mpc-577.pdf
University Transportation Center (UTC) project information at
https://www.mountain-plains.org/research/downloads/2018-mpc-577-project-update.pdf
From the UTC project information: The use of Light Detection and Ranging (LiDAR) technology has been growing in the transportation industry in recent years. The technology has been proven to provide precise, accurate and high-density point clouds that can be related to a global reference frame (El-Sheimy et al., 2005; Shan and Toth, 2009). Extensive research in the area has shown how this technology can be used for anything from construction quality control to safety assessments to infrastructure management (e.g.[,] Yu et al., 2015; Riviero et al., 2016; Pu et al., 2011; Geiger etal., 2012; Lato et al., 2012; He et al., 2017, Neupane et al., 2018; Rister et al., 2018).

Of particular interest for this project proposal is how transportation agencies can utilize the Big Data that will result from a growing fleet of autonomous vehicles. Agencies have had experience with Big Data in the past (Zhao et al., 2018). However, the Big Data of autonomous vehicles is likely to be of unprecedented magnitude (e.g.[,] Matthews, 2018; Marr, 2017; Clerkin, 2017). How will agencies handle such a data set, should they choose to collect it? How much data can agencies expect from a variety of different scenarios? Will they need to filter the data they receive? How many uses can they get out of these data? This proposed project will help agencies answer some of those questions.

Washington

LiDAR for Data Efficiency, Kin S. Yen, Bahram Ravani and Ty A. Lasky, Washington State Department of Transportation, September 2011.
https://www.wsdot.wa.gov/research/reports/fullreports/778.1.pdf
From the conclusions and recommendations appearing in the executive summary: The study shows a cost efficiency that could be realized over time with using Mobile LiDAR to supplement or replace existing WSDOT [Washington State DOT] operations and processes. Purchasing and operating a Mobile LiDAR system has the potential to generate considerable savings, while meeting most WSDOT business requirements, although there are some key implementation issues that must be addressed. These include funding, procurement methods, organizational structure, compatibility, integration with existing data systems, best practices, accuracy standards, and universal user access to point cloud data. Further study to examine these and other implementation issues will provide the basis to best utilize this emerging technology of Mobile LiDAR in WSDOT business areas.

Contacts

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Appendix A: Survey Questions

The following survey was distributed to members of two American Association of State Highway and Transportation Officials (AASHTO) committees:

- Subcommittee on Asset Management.
- Committee on Performance-Based Management.

In addition, the survey was distributed to a representative of the North Carolina Department of Public Safety who was expected to have experience with a coordinated statewide approach to asset data collection and management.

Statewide Asset Data Collection and Management

(Required) Has your agency established a coordinated statewide approach to collecting and managing data on a range of agency assets?

- No (directs the respondent to **Agencies Without a Statewide Program to Collect and Manage Asset Data**)
- Yes (directs the respondent to **Agencies With a Statewide Program to Collect and Manage Asset Data**)

Agencies Without a Statewide Program to Collect and Manage Asset Data

Is your agency considering establishing a new program or expanding its practices to allow for a coordinated statewide approach to multiasset data collection and management?

- No
- Yes (please briefly describe your agency's discussions or plans)

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

Agencies With a Statewide Program to Collect and Manage Asset Data

Program Description

1. How long has your agency collected and managed multiasset data statewide in a coordinated fashion at the enterprise level?
    - 0 to 2 years
    - 2 to 5 years
    - 5 to 7 years
    - 7 to 10 years
    - Other (please specify)
2. Please describe your agency's approach to coordinated statewide multiasset data collection and management.
    - Hire a consultant to collect, store and analyze data
    - In-house staff conducts the data collection and related activities
    - Other (please describe)

3. How often does your agency coordinate and collect data at the enterprise level?
    - Annually
    - Every 2 years
    - Every 3 years
    - Other (please describe)
4. On what roadways does the state collect asset data? Select all that apply.
    - All public roads
    - State roadways
    - Local roadways
    - National Highway System only
    - Ramps and connectors
    - Other (please describe)
5. Has your agency adopted or published standards or procedures for its enterprise statewide program to collect and manage asset data?
    - No
    - Yes (Please respond to Question 5A.)

5A. Please briefly describe these standards or procedures. If documented, please provide a link or send any files not available online to carol.rolland@ctcandassociates.com.

Collecting Asset Data

1. Please describe the core or critical set of assets your agency collects. What specific types of assets does your agency collect? Select all that apply.
    - Barrier (i.e., guardrail)
    - Bridges
    - Cabinets
    - Drainage features/culverts
    - Intelligent transportation systems
    - Lands and buildings
    - Loop detectors
    - Marking reflectivity
    - Model Inventory of Roadway Elements (MIRE)
    - Pavement
    - Pavement markings
    - Ramp meters
    - Right of way
    - Roadside facilities
    - Roadside features
    - Sign reflectivity
    - Signal post
    - Signs
    - Structures/walls
    - Other (please describe)
2. What technology, tools and methods are used to collect and extract asset data? Select all that apply.
    - GPS devices
    - LiDAR (airborne)
    - LiDAR (terrestrial)
    - Manual data collection
    - Mobile devices (smartphone, tablet)
    - Multisensor mobile mapping platforms
    - Photogrammetric processes
    - Photolog
    - Surface geophysics
    - Unmanned aerial systems
    - Windshield survey
    - Other (please describe)
3. Who performs the field asset data collection, extraction and management?
    - Agency staff
    - Contractor
    - Both (depends on the asset)
    - Other (please describe)
4. Please describe how your agency coordinates the statewide data collection to meet the competing demands for the type and extent of the asset data without duplicating efforts.

5. Does your agency have a data quality management plan or something similar for data collection?
    - No, we don't have a plan.
    - Yes, we have a plan but can't share it.
    - Yes, we have a plan and can share it. (Please respond to Question 5A.)

5A. Please provide a link to your agency's data quality management plan or send any files not available online to carol.rolland@ctcandassociates.com.

6. Does your agency collect asset data during the project delivery phases (design through construction) that is entered into asset management information systems for future use?
    - No
    - Yes

Managing Asset Data

1. What products from the data collection and extraction efforts are made available to staff? Select all that apply.
    - Extracted assets
    - Imagery
    - Point cloud
    - Other (please describe)

2. How is asset data made available to staff? Select all that apply.
    - Agency-hosted web-based application
    - Consultant-hosted web-based application
    - Enterprise data warehouse
    - Multiple data marts
    - On-premise file server
    - Separate databases
    - Separate geodatabases
    - Web services
    - Other (please describe)

3. From the perspective of your agency's unified statewide data collection effort, please describe how asset data is migrated from mobile or other collection practices to where it is stored.

4. In what format is the data from your agency's statewide asset collection effort delivered?
    - Vendor proprietary format, although a perpetual license is provided to the state
    - Standard format that is open to a third party, allowing full access of the data
    - Other format (please describe)

4A. Please use the space below to provide any additional comments about the format(s) data is delivered in.

Assessing Agency Practices

1. What successes has your agency experienced in connection with a coordinated statewide asset data collection and management strategy?

2. What challenges has your agency experienced in connection with collecting and managing asset data using a statewide approach?

3. What are your top three recommendations for other agencies developing a coordinated statewide program to collect and manage asset data?

4. Please provide links to documents associated with your agency's statewide asset data collection and management efforts (other than those you have already provided). Send any files not available online to carol.rolland@ctcandassociates.com.

Wrap-Up

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