# Roadway Safety Hardware Asset Management Systems Case Studies

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## FOREWORD

Since the early 1990s, the term "asset management" has grown to embrace a broad array of tasks and activities aimed at identifying, assessing, prioritizing, evaluating, maintaining, rehabilitating, renewing, preserving, improving, and managing assets. This report addresses asset management of roadway safety hardware in the United States. Increasingly refined and complex tools such as modern bridge and pavement inventory management systems have been developed and adopted by many State departments of transportation (DOTs), as well as some of the larger departments of county and municipal governments. Many of these management systems have been developed cooperatively by pooling funds and in other ways, such as assistance from the Federal Highway Administration (FHWA).

Through maintenance and enhancement efforts, these software systems are growing in their robustness and capability to deal effectively with complex, real-world issues and conditions. One software management area that has not advanced as rapidly is roadway safety hardware inventory, which includes an array of signs, signals, roadway lighting luminaries, support structures for signs, guardrails, pavement markings, and deployed detecting devices—all vital to safe, efficient highway operations.

This study provides information to State DOTs on roadway safety hardware management systems that would help increase their use of state-of-the-practice techniques. This report was developed for State DOT personnel, particularly chief engineers and other top management, involved with the planning, funding, and execution of roadway safety hardware management systems.

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# SI* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 645.2 | square millimeters | $mm^2$ |
| $ft^2$ | square feet | 0.093 | square meters | $m^2$ |
| $yd^2$ | square yard | 0.836 | square meters | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | square kilometers | $km^2$ |
| | | **VOLUME** | | |
| fl oz | fluid ounces | 29.57 | milliliters | mL |
| gal | gallons | 3.785 | liters | L |
| $ft^3$ | cubic feet | 0.028 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | cubic meters | $m^3$ |
| | | NOTE: volumes greater than 1000 L shall be shown in $m^3$ | | |
| | | **MASS** | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") |
| | | **TEMPERATURE (exact degrees)** | | |
| $^oF$ | Fahrenheit | 5 (F-32)/9 or (F-32)/1.8 | Celsius | $^oC$ |
| | | **ILLUMINATION** | | |
| fc | foot-candles | 10.76 | lux | lx |
| fl | foot-Lamberts | 3.426 | candela/$m^2$ | cd/$m^2$ |
| | | **FORCE and PRESSURE or STRESS** | | |
| lbf | poundforce | 4.45 | newtons | N |
| lbf/$in^2$ | poundforce per square inch | 6.89 | kilopascals | kPa |

## APPROXIMATE CONVERSIONS FROM SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.039 | inches | in |
| m | meters | 3.28 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| | | **AREA** | | |
| $mm^2$ | square millimeters | 0.0016 | square inches | $in^2$ |
| $m^2$ | square meters | 10.764 | square feet | $ft^2$ |
| $m^2$ | square meters | 1.195 | square yards | $yd^2$ |
| ha | hectares | 2.47 | acres | ac |
| $km^2$ | square kilometers | 0.386 | square miles | $mi^2$ |
| | | **VOLUME** | | |
| mL | milliliters | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | gallons | gal |
| $m^3$ | cubic meters | 35.314 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.307 | cubic yards | $yd^3$ |
| | | **MASS** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.202 | pounds | lb |
| Mg (or "t") | megagrams (or "metric ton") | 1.103 | short tons (2000 lb) | T |
| | | **TEMPERATURE (exact degrees)** | | |
| $^oC$ | Celsius | 1.8C+32 | Fahrenheit | $^oF$ |
| | | **ILLUMINATION** | | |
| lx | lux | 0.0929 | foot-candles | fc |
| cd/$m^2$ | candela/$m^2$ | 0.2919 | foot-Lamberts | fl |
| | | **FORCE and PRESSURE or STRESS** | | |
| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | lbf/$in^2$ |

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

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## Abbreviations and Acronyms

| | |
|---|---|
| AADT | Average Annual Daily Traffic |
| AASHTO | American Association of State Highway and Transportation Officials |
| AFMS | Automated Facilities Management System |
| AMS | Asset Management System |
| BMP | Begin Mile Point |
| BPR | Business Process Reengineering |
| CAD | Computer Aided Design |
| Caltrans | California Department of Transportation |
| CMS | Construction Management System |
| COTS | Commercial off-the-shelf |
| DMI | Distance Measuring Instrument |
| DMS | Document Management System |
| DOT | Department of Transportation |
| EIS | Executive Information System |
| FDOT | Florida Department of Transportation |
| FHWA | Federal Highway Administration |
| FMIS | Financial Management Information System |
| FRD | Functional Requirements Document |
| FWD | Falling Water Device |
| GASB | Government Accounting Standards Board |
| GB | Gigabyte |
| GDOT | Georgia Department of Transportation |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| HMIS | Highway Management Information System |
| HMMS | Highway Maintenance Management System |
| HPMS | Highway Performance Monitoring System |
| HSMS | Highway Sign Management System |
| ICAS | Inventory and Condition Assessment System |
| IMS | Infrastructure Management Service |
| IMMS | Inventory or Integrated Maintenance Management System |
| IMU | Inertial Motion Unit |
| INS | Inertial Navigation System |
| ISTEA | Intermodal Surface Transportation Efficiency Act |
| IT | Information Technology |
| MAL | Master Asset List |
| MDSHA | Maryland State Highway Administration |
| MMS | Maintenance Management System, Marking Management System |
| MMSI | Maintenance Management System Improved |
| Mn/DOT | Minnesota Department of Transportation |
| NCDOT | North Carolina Department of Transportation |

## Abbreviations and Acronyms—Continued

| | |
|---|---|
| NCHRP | National Cooperative Highway Research Program |
| NMSHTD | New Mexico State Highway and Transportation Department |
| ODOT | Oregon Department of Transportation |
| OIS | Office of Information Systems |
| PDA | Personal Digital Assistant |
| PMS | Pavement Management System |
| POS™ | Position Orientation System |
| PPRM | Program, Project, and Resource Management System |
| PPS™ | Pavement Profile Scanner |
| QA/QC | Quality Assurance/Quality Control |
| QAR | Quality Assurance Review |
| R2Sign | Sign Management System |
| RAM | Random Access Memory |
| RCA | Random Condition Assessment |
| RCI | Roadway Characteristics Inventory |
| RFI | Roadway Feature Inventory |
| RFP | Request for Proposal |
| RMAN | Recovery Manager |
| SAIC | Science Applications International Corporation |
| SCDOT | South Carolina Department of Transportation |
| SCOH | Standing Committee on Highways |
| SHA | State Highway Administration |
| SHTD | State Highway and Transportation Department |
| SIMS | Sign Inventory Management System |
| Stereo RST | Stereo Road Surface Tester |
| TAMS | Transportation Asset Management Service |
| TB | Terabytes |
| TDOT | Tennessee Department of Transportation |
| TranStat | Transportation Statistics Office |
| TRB | Transportation Research Board |
| TRIMS | Tennessee Roadway Information System |
| TRIS | Transportation Research Information Services |
| TSIIM | Traffic Structure Inventory Inspection and Maintenance |
| TSIS | Traffic Signal Information System |
| TSSI | Traffic Signal System Inventory |
| USDOT | United States Department of Transportation |
| VCMS | Vertical Clearance Measurement System |
| VCR | Videocassette Recorder |
| VDOT | Virginia Department of Transportation |
| WisDOT | Wisconsin Department of Transportation |

# CHAPTER 1. INTRODUCTION

## BACKGROUND

Since the early 1990s, the term "asset management" has grown to embrace a broad array of tasks and activities aimed at identifying, assessing, prioritizing, evaluating, maintaining, rehabilitating, renewing, preserving, improving, and managing assets. This report addresses asset management of roadway safety hardware in the United States. Increasingly refined and complex tools such as modern bridge and pavement inventory management systems have been developed and adopted by many State departments of transportation (DOTs), and larger departments of county and municipal governments. Many of these management systems have been developed cooperatively by pooling funds and in other ways, such as with assistance from the Federal Highway Administration (FHWA)**.**

Through maintenance and enhancement efforts, these software systems are growing in their robustness and capability to deal effectively with complex, real-world issues and conditions. Clearly, the ability of the State DOTs to meet future challenges in an era of rapid social and political change and with ever-scarcer resources will depend in no small measure on the intelligent deployment of asset management technologies.

One software management area that has not advanced as rapidly is roadway hardware, which refers to an array of signs, signals, roadway lighting luminaries, support structures for signs, signals, guardrails, pavement markings, and deployed detecting devices. Collectively, these roadway hardware categories are vital to the safe and efficient operation of highways.

Many roadway hardware devices degrade relatively quickly in the face of traffic stress, snow and ice conditions that often entail chloride applications and repeated freeze-thaw cycles, and other environmental factors. These systems must be monitored closely and their underlying inventory systems updated regularly and frequently. The impairment or ineffectiveness of certain system components may not be discernable through simple visual inspection. For example, sign retroreflectivity deteriorates steadily from the day of its deployment, but certain specialized equipment can determine its level of performance at any time. Also, nonfunctioning, embedded magnetic loop detectors are both commonplace and invisible to the visual inspector. The appropriateness of well-designed management systems to monitor and give timely and accurate indication of the need to maintain, rehabilitate, or replace components hardly seems debatable. And yet, the pressure of other needs and priorities has led some DOTs to devise and use inadequate asset management systems or, worse, to have no systematic approach at all.

The significance of new financial reporting standards established by the Governmental Accounting Standards Board (GASB) in 1999 must not be ignored. These new standards fundamentally changed the practices of State and local governments in reporting their financial results, providing an important opportunity for State DOTs to increase public recognition of the worth of roadway safety assets in terms of their financial value to the States.

Among other provisions, GASB Statement 34 (GASB 34), "Basic Financial Statements—and Management's Discussion and Analysis—for State and Local Governments," requires that major infrastructure assets acquired or receiving major additions or improvements in fiscal years beginning after June 15, 1980, be capitalized in financial statements.(1) This means that governments with more than $100 million in total annual revenues (which includes all States) were required to report on new infrastructure assets starting in the fiscal year beginning after June 15, 2001, with reporting of previously acquired infrastructure assets 4 years later.

As a result, GASB 34 provides transportation agencies with the opportunity to make other State and local officials, as well as the public at large, more aware of the value of the significant transportation assets that governments own and operate and the maintenance they require. Increased awareness of the importance of investment in these assets highlights the need to preserve their condition.

## OBJECTIVES

The objective of this study is to provide information to State DOTs on roadway safety hardware management systems that would help increase their use of state-of-the-practice techniques. The research team conducted a review of current practices by DOTs that use fully or semi-integrated asset management systems. The team identified features and characteristics of the different asset management systems in use or under development in State DOTs. They worked closely with FHWA and the American Association of State Highway and Transportation Officials (AASHTO) committees and staff, including the AASHTO Roadside Hardware Asset Management Task Force and the AASHTO Standing Committee on Highways (SCOH), Subcommittees on Traffic Engineering and Maintenance.

The intention of this report is to give an understanding of the wide-ranging benefits of an effective roadway safety hardware asset management system, including one or more of the following capabilities:

- Properly establish and maintain a collection of safety hardware that is operating at optimal efficiency statewide.
- Enhance the ability to make rational and cost-effective resource allocation decisions based on complete information, centralized resource tracking, and more accurate cost data.
- Reduce costs for acquisition, maintenance, upgrade, and replacement of assets following improved ability to assess needs and make resource allocation decisions.
- Improve ability to gather and analyze data in a timely and effective manner that supports overall information management and reporting activities.
- Increase ability of management to assign and oversee the efficient completion of work orders and routine maintenance tasks and reduce duplication of effort.
- Decrease State legal liability that results from gaps in appropriate safety hardware installation.

### Target Audience

This report was developed for State DOT personnel involved with the planning, funding, and execution of roadway safety hardware management systems. The primary target audience is chief engineers and other top management in State transportation agencies. Other intended audiences include senior State DOT officials, FHWA safety engineers, and FHWA division administrators. Other State DOT officials who would benefit from reviewing this report include technical directors in charge of traffic and maintenance programs and district managers.

## Scope of Roadway Hardware Assets

The terms "asset management," "roadway assets," and "roadway safety hardware" have different uses in various State DOTs; however, AASHTO interprets the term "transportation asset management" as a "strategic approach to managing transportation infrastructure."[2] The FHWA Office of Asset Management defines the term and its principles in specific language: "Asset management is a set of business principles and best practice methods for improving resource allocation and utilization decisions. It reflects a comprehensive view of system management and performance."

Following is a list of the FHWA Office of Asset Management core principles of asset management:

> *Policy Driven:* Resource allocation decisions are based on a well-defined set of policy goals and objectives. These objectives reflect desired system condition, level of service, and safety provided to customers, and typically are tied to economic, community, and environmental goals.
>
> *Performance Based*: Policy objectives are translated into system performance measures that are used for both day-to-day and strategic management.
>
> *Analysis of Options and Tradeoffs*: Decisions on how to allocate funds within and across different types of investments such as preventive maintenance versus rehabilitation, pavements versus bridges, capacity expansion versus operations, different modal mixes, and safety are based on an analysis of how different allocations can affect achievement of relevant policy objectives. Alternative methods for achieving a desired set of objectives are examined and evaluated.
>
> *Decisions Based on Quality Information*: The merits of different options for an agency's policy goals are evaluated using credible and current data. Where appropriate, decision-support tools are used to provide easy access to needed information and assist with performance tracking and predictions.
>
> *Monitoring to Provide Clear Accountability and Feedback*: Performance results are monitored and reported for both resulting effects and effectiveness. Feedback on actual performance may influence agency goals and objectives, as well as resource allocation and utilization decisions.[3]

State DOTs maintain a large number of assets along the roadside. The functions of many of these assets include providing safer driving conditions for the public. For this study, the FHWA specified the following seven categories of assets for study:

- Roadway signs.
- Signals.
- Roadway lighting.
- Supports and structures for signs, signals, and lighting.
- Guardrails, barriers, and crash cushions.

- Pavement markings and treatments.
- Detectors.

Each asset management system in the case studies described in chapter 2 is limited to systems that manage one or more of these seven assets. In each case study, a table summarizes the list of assets collected from these seven categories.

## RESEARCH METHODOLOGY

FHWA and AASHTO believe a key mission is to develop and promulgate effective roadway safety hardware management systems. Both organizations believe such systems are vital to the efficient preservation of the vast public investment in transportation facilities and infrastructure. FHWA demonstrated its commitment several years ago in its reorganization by establishing the Office of Asset Management. Assets such as warning and regulatory signs, edge lining, signals, and roadway lighting have virtually no other purpose than fostering and enhancing highway safety.

State DOTs have been leading the way in asset management for a decade or more. The work of the AASHTO Task Force on Transportation Asset Management has been prodigious in guiding numerous advances. In the field of roadway hardware specifically, the ad hoc Roadside Hardware Management Steering Committee has been crucial to progress, and it will be vital to the success of this and other successor projects.

The success of this effort has depended largely on close coordination with representatives of the participating FHWA organizational units and the AASHTO Steering Committee. Coordination took place through mail and e-mail exchanges as well as face-to-face interaction with the AASHTO group over the course of the project.

Following is a list of steps followed to complete this project:

1. *Survey of State DOTs.* The January 2000 AASHTO survey provided a starting point for this task. Individual responses were sought from the AASHTO offices, and the nearly 40 responses were examined individually. A State that indicated it was implementing or planning an asset management system was contacted by telephone or e-mail and asked about tools in use. It was recognized at the beginning of this research that the survey was more than 2 years old. The research team sought updated information through these contacts and the FHWA division offices. Appendix A contains a copy of the letter to FHWA division offices seeking updated information about State activities. Appendix B contains the questionnaire sent to State DOTs. Appendix C contains a summary of the survey results. Appendix D lists the State DOT contacts.

2. *Literature Review.* A literature review was desirable because the tools in use were more likely to be from such source documents than from the survey summary. Additional relevant literature leads were sought through interviews with FHWA and AASHTO staff and a Transportation Research Information Services (TRIS) search. The results of the literature search appear in the bibliography.

3. *Selected Examples of Best Practices.* The principal resources for this task were the members of the AASHTO Steering Committee along with the designated representatives of the three

participating FHWA offices. Most of the States that indicated any type of automated asset management system in the AASHTO survey were contacted. A number of States that did not respond to the AASHTO survey were also contacted. Through consultation with these project sponsors and extensive phone interviews, eight States were chosen for case studies.

4. *Conducted Case Study Field Visits.* The research team scheduled 1- to 2-day visits with the selected State DOTs. The field visits to the States were preceded by telephone calls and e -mails aimed at identifying key contacts in each location, establishing firm appointments, and, most important, soliciting and collecting key documents before each visit. During the visits, the research team interviewed senior managers, maintenance and traffic engineers, technical staff, and State DOT contractors to collect more in-depth information and resources. All information in the case studies was collected from the interviews with the State DOT staff, and it is based on reference documents provided by the States. Most of the States had limited documentation for their systems; most of the available documents were user manuals. The information in the case studies was collected in an outline format using responses to 17 questions about each system, as listed in appendix B.

## ASSUMPTIONS

Although the key assumption in a project such as this one is that the findings obtained in a small sample of State DOTs can apply to the broad universe of these State agencies, the projects that were examined in detail through field visits or extensive telephone interviews, or both, varied significantly from one another in program details. This results principally from the specific history and circumstances in each State; for example, the needs of Virginia, which has the third largest State-maintained highway system in the country, are significantly different from those of a State such as Arizona, whose asset management system includes landscape features. As a result, some care and judgment is advisable when reviewing some of the lessons learned.

## FOUNDATIONS OF THE APPROACH

Personnel responsible for managing highway assets are faced with a mature roadway transportation system that is experiencing high and growing demand. In addition, personnel must cope with the problems of deterioration associated with aging assets while also being expected to provide high-quality service. Transportation officials face increasingly constrained funding and competition with other States agencies for limited financial resources.

One way to help in making cost-effective resource allocation decisions is through the use of asset management systems. The resulting decisions are strategic rather than tactical because they account for all assets under the transportation agency’s umbrella for an extended time horizon. An asset management approach has at its foundation technical, fact-based information for decisionmaking, and it is driven by goals, policies, and budgets.

The technical information supporting the asset management framework is derived from engineering, economic, performance, and behavioral models. Raw data such as inventory statistics are also required to make asset management work. The ability to gather timely, useful technical information that is critical to asset management is possible through the technological revolution resulting from faster, more capable computers.

Performance goals reflect input from citizens, legislators, and policymakers, and they provide a focal point from which transportation officials may explain their programs and performance to the public. In addition, performance goals assist transportation executives in identifying and focusing on critical system requirements.

Implementing an asset management framework provides not only the means to identify optimal investment strategies, but also offers a way to articulate them. These capabilities arise from the transportation agency having the ability to weigh one alternative against another—or to conduct what-if analyses. For example, an agency faced with a possible decrease in funding can readily demonstrate the effect on the condition and performance of a system, and then its effect on the overall safety of State roadways. It should be noted that the application of asset management varies significantly from organization to organization.

# CHAPTER 2. CASE STUDIES OF STATE DOT ROADWAY SAFETY HARDWARE MANAGEMENT SYSTEMS

## APPROACH TO SELECTION CRITERIA

In January 2000, AASHTO conducted a survey of State DOTs to evaluate the practices of roadway safety hardware asset management systems. In October 2002, FHWA initiated a follow-up e-mail to all FHWA division offices inquiring about updates to the information States provided to the 2000 AASHTO survey. A copy of the correspondence with the FHWA division offices appears in appendix A. A list of the survey questions appears in appendix B. The FHWA division offices provided no updates based on that inquiry.

According to the AASHTO study, only one-third of the State DOTs use a hardware management system. A summary of the survey results appears in appendix C. The research team used the AASHTO survey as the basis for its initial approach to State DOTs that indicated use of some type of an asset management system.

The research team took the following steps to identify States with fully or semi-integrated roadway safety hardware management systems:

- Contacted the 42 States (out of the 52 States surveyed) that responded in the 2000 AASHTO survey.
- Canvassed FHWA division offices for updates in October 2002; no additional information was received.
- Contacted potential candidate State DOTs based on initial survey results.
- Pursued new leads generated from contacts with States.
- Pursued selected States that did not respond to the survey.
- Conducted follow-up contacts with potential candidate States.

After a comprehensive search for candidate States, the team narrowed the number of candidates for field visits and case studies using the following considerations:

- States that had implemented any integrated roadway hardware asset management system.
- States that had initiated a prototype asset management system.
- States with fully or semi-automated methods of inventory and monitoring of a partial number of assets.
- States willing to share information on lessons learned from systems that are not fully successful.
- States that had outsourced an integrated asset management system.
- Quality and innovation of roadway hardware asset management systems.

The research team worked closely with FHWA and AASHTO members during the selection process and briefed the project principals during all the stages of research.

## STATES SELECTED FOR CASE STUDIES

The research team conducted site visits and held numerous discussions with officials from State DOTs, FHWA, and AASHTO. Several States that use a single-asset system are discussed briefly later in this chapter as a sample of typical systems that are in place in many States.

This document presents two detailed State model integrated asset management systems, Virginia and New Mexico, which are discussed in more detail in the case studies later in this chapter. Six additional States were selected for case studies:

- California.
- Florida.
- Georgia.
- Maryland.
- Minnesota.
- Tennessee.

The research team visited seven of the State DOTs and collected information by phone interviews from Florida.

This chapter also contains brief descriptions of a few other States with typical asset management systems (that is, nonintegrated, single-asset management systems):

- North Carolina.
- Oregon.
- Wisconsin.

A number of other States have similar systems in place. The States reported here represent just a sample of the type of systems implemented.

During the site visits, the research team met with senior management personnel and technical managers including State DOT and contractor staff in some of the following positions:

- Chief engineer.
- Office director.
- State maintenance engineer.
- State traffic engineer.
- System project managers and technical staff.
- Information technology (IT) department staff.
- Contractors developing the systems.

The research team conducted interviews and viewed brief system demonstrations in each State visited, collected available documentation, and followed up after the meeting to collect additional information.

## MODEL INTEGRATED ASSET MANAGEMENT SYSTEMS

The FHWA Office of Asset Management defines data integration as the "process of combining or linking two or more data sets from different sources to facilitate data sharing, promote effective data gathering and analysis, and support overall information management activities in an organization." Information about roadside assets and the process for sharing this information is critical to successful asset management; therefore, an integrated asset management system is highly desirable and results in increased effectiveness.

As the different systems in each State were studied, it became clear that few State DOTs have implemented integrated systems to manage all seven asset categories identified for this study (roadway signs; signals; roadway lighting; supports and structures for signs, signals and lighting; guardrails and barriers; pavement markings and treatments; and detectors). Most States have implemented asset management for one or more of the asset categories and put several nonintegrated systems in place.

Two different models of integrated asset management systems emerged as seeming the most progressive among the States in this study. These models, New Mexico and Virginia, present a different approach to the integrated system of managing roadway hardware.

New Mexico uses a video system to capture roadway assets and extracts detailed data for each asset from the video image. A feature called "Virtual Drive" allows system users to simulate driving along any roadway in the State system and view clearly and accurately the hardware along the route. Virginia envisioned managing its assets through its entire life cycle—condition assessment, planning, alternatives evaluation, project development, and implementation. An initial system module was developed based on an inventory system with a statistical, random sampling using manual data collection.

Following is a discussion of these two State DOT systems.

### New Mexico State Highway and Transportation Department

The New Mexico State Highway and Transportation Department (NMSHTD) provides one model of a fully integrated asset management system. NMSHTD has two primary asset management systems: Road Feature Inventory (RFI) and Highway Maintenance Management Systems (HMMS), described in the following paragraphs.

#### *Road Feature Inventory System Description*

The NMSHTD Road Feature Inventory RFI system maintains an extensive database on the entire New Mexico roadway system to ease maintenance and limit legal liability by documenting safety assets. Images have been captured statewide at every 15.24 m (50 ft) of highway with a video image width of 36.58 m (120 ft).

Along with the images, information is collected on the NMSHTD roadway safety assets and roadway features. The result is a database, the RFI, of more than 5 million images and their associated data, forming the foundation for a number of applications used to manage the State's highway assets.

The RFI project started in June 2001 when NMSHTD engaged a contractor for data collection. The contractor is collecting data on all right-of-way assets on all NMSHTD-maintained roads.

The development of the RFI application and database was initiated in-house by the Highway Operations IT development staff, assisted by a contractor.

Video images have been filmed on approximately 24,140.16 kilometers (km) (15,000 miles (mi)) of centerline on roads operated by the State, and approximately 690,000 assets on State highways have been inventoried using video taken in each driving lane. The van that captures the video can be driven at up to 88.51 kilometers per hour (km/h) (55 miles per hour (mi/h)) running speed. Each NMSHTD district is divided into DOT patrols that maintain specified areas. The video is identified by districts and patrol number.

When the application is fully implemented, patrol personnel will be equipped with Global Positioning System (GPS)-enabled personal digital assistants (PDAs) and either a digital camera laptop or a pen tab and a digital camera. Personnel can update, insert, or delete assets from their PDA laptop and then synchronize with the database when they return to the office. Because so much of New Mexico is rural, wireless access to the application is not an option. An image will be associated with each new asset added to the database or changes made to an asset.

One of the two main components of RFI is reporting. The reporting component interfaces to the HMMS that districts use to enter daily work reports and maintain stockpile and similar information. At the time of this writing, NMSHTD has plans to integrate the RFI and HMMS applications to maximize efficiency and provide data integrity. For example, a user who enters a work order for a guardrail is directed to the RFI application to update the relevant inventory. The RFI application feeds the HMMS system to reflect updates to the RFI database for maintenance done on the road, which keeps the inventory current. Users access the system through an Oracle® portal to generate reports using Oracle Reports Builder® and Discoverer® applications.

Figure 1 shows a typical van used to collect the video images. The van is fully equipped with cameras, computer equipment, and lasers to capture pavement conditions and road geometry.


**Figure 1. Photo. Data collection van.**

The report feature incorporates images stored in the database with the data. Figure 2 shows a sample image of an RFI report interface.

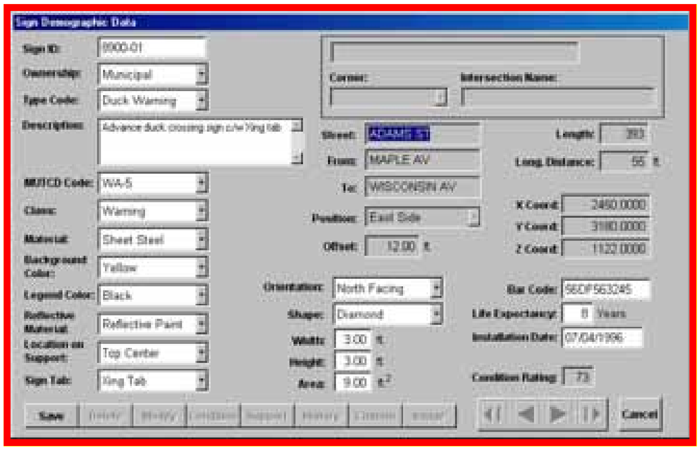


**Figure 2. Screen Capture. Sample image in the New Mexico RFI application.**

The second main component of the RFI application is known as "Virtual Drive." By choosing a route, a direction, and start mileposts and end mileposts, a user can take a tour of the route on the computer screen. Users can interact with the application much like a videocassette recorder (VCR), pressing a button (similar to the "play" button) to create the effect of driving down the chosen route and viewing the images one after another. All departments at the NMSHTD will be able to use the Virtual Drive feature to improve their asset management capabilities. For example, the State Maintenance Bureau will be able to use Virtual Drive to pinpoint an area of highway that needs maintenance or lacks appropriate signage. Periodic comparisons to historical records can help identify missing signage. The legal department will be able to use the Virtual Drive to verify if the route was safely signed or if a guardrail was located where it needed to be. Figure 3 shows a Virtual Drive screen capture of a sample image comparison. Figures 4 through 7 show additional RFI images.

**Figure 3. Screen capture. Comparison of sample images in the New Mexico RFI Virtual Drive application.**


**Figure 4. Screen capture. Sample RFI image showing roadside guardrail.**


**Figure 5. Photo. Sample RFI image showing interstate sign.**


**Figure 6. Screen capture. Sample RFI application screen with thumbnail image.**

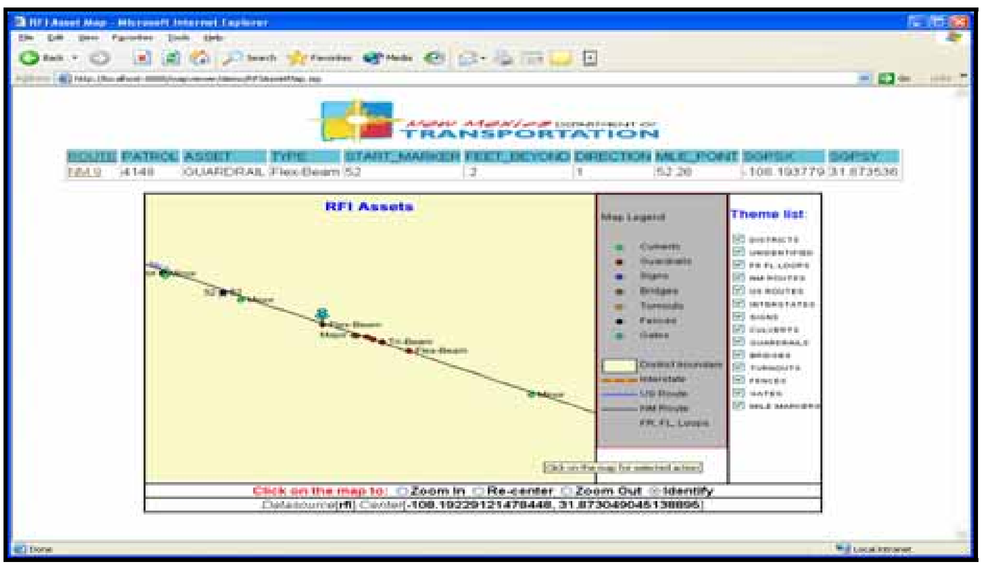


**Figure 7. Screen capture. Sample New Mexico RFI spatial map with assets identified.**

Of the seven asset categories in the FHWA project, only lighting and detectors are not included in the New Mexico program. In New Mexico, lighting is maintained by local governments, not the State DOT. Nonetheless, the video can easily pick up the roadway lighting information as well. The State is eliminating the use of magnetic detectors and making a transition to the use of video technology. Table 1 lists the asset category of data collected in the New Mexico RFI program.

**Table 1. New Mexico RFI data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | √ |
| Signals | √ |
| Roadway Lighting | – |
| Supports and Structures for Signs, Signals, and Lighting | √ |
| Guardrails, Barriers | √ |
| Pavement Markings and Treatments | √ |
| Detectors | – |

Data on assets are collected based on a master asset list (MAL). Some fields from the MAL initially will be empty and populated continuously (for example, installation dates). Assets can be broken down into either point assets such as signs or linear assets such as guardrails that have a start and end point. Table 2 lists assets in each category.

**Table 2. New Mexico RFI asset types.**

| Asset Type | Asset List |
|---|---|
| Point assets | Ditches, gates, cattleguard, traffic signal, culverts, drainage structures, delineators, overhead structures, signs, median crossover, turnouts, bridge, interchange, junction, utilities crossing, infrastructure location, ports of entry, border patrol check stations, rest area, emergency services location, railroad crossing, drop inlet |
| Linear assets | Highway section, low water crossing, mowing, noxious weed section, fences, barrier walls, pavement markings, erosion control devices, delineators, guardrails |

The RFI project has identified 31 types of assets and their respective attributes or characteristics, listed in table 3. Each asset has common attributes such as description; condition; material; X, Y, and Z coordinates; start and end milepost; start and end mile point; height; and length. Some asset attribute information varies depending on the asset type. Note that these assets types were determined by the New Mexico RFI project for its own program and may vary from other States' asset definitions.

**Table 3. The 31 RFI assets and their definitions.**

| No. | Asset | Asset Definition |
|---|---|---|
| 1 | Highway section | A section of road, designated as being State owned, having a specific start and end point, with relatively uniform construction throughout. New sections should be started where the attributes change (for example, number of lanes, surface type, shoulder width) |
| 2 | Ditches | This is a man-made cut in the ground. The start of the structure is identified by the left-most point, closest to the road surface, when first observed. |
| 3 | Low water crossing | Naturally occurring or man-made features that allow vehicle to wade through when little or no water exists. Cannot be forded in high-water conditions. |
| 4 | Mowing | Areas along the highway section designated specifically for controlling vegetation growth. By default it is everywhere except where no vegetation is evident. |
| 5 | Noxious weed section | Vegetation that is not native to the area or is threatening to take over the area from other indigenous species. |
| 6 | Fences | Structures used along the highway section to separate different areas. Every time the fence construction changes, a new asset is to be defined. |
| 7 | Gates | A structure used for restricting entry to the highway section. Can also be used for controlling entry to NMSHTD or other properties. |
| 8 | Cattle guard | These devices are used to prevent livestock from crossing or entering roadways. |
| 9 | Barrier walls | The barrier wall is, in most cases, found close to the outside edge of the highway pavement or section right-of-way. At the edge of roadway, it is typically a concrete barrier to deflect traffic and at the edge of right-of-way typically a high wall to separate traffic noise from residential areas, or other traffic. Starting measurement is made at the leading base edge. |
| 10 | Pavement markings (stripe items) | Lines and symbols on the travel surface of the highway section. |
| 11 | Traffic signal | Light or series of lights used for controlling the flow of traffic. Each signal head is to be inventoried separately using the *same* supporting structure—differentiated by the attribute "position of head." The position is to be calculated to the base of the support closest to the right edge of the travel lanes. |
| 12 | Culverts | These structures pass under the roadway and are normally open on both ends. |
| 13 | Drainage structures | These devices are used to drain water from the road surface and are found most often along the right edge/side of the road. Structures in the median or the left side of a divided road are inventoried under drop inlets. |
| 14 | Erosion control devices | A definition of the way water and soil movement is controlled or restricted. |
| 15 | Delineators | These are markers placed along the edge of the highway section to identify hazards, edge of pavement, or note distance and highway information. Edge of road posts are treated as a linear assets, tenth-mile markers are summed by highway section, other types of delineators are to be treated as point assets, such as a culvert delineator. |

**Table 3. The 31 RFI assets and their definitions—Continued**

| No. | Asset | Asset Definition |
|---|---|---|
| 16 | Overhead structures | Overhead structures do not include railways. The location is measured at the bottom left point of the base of the structure, to the right of the travel surface. |
| 17 | Signs | Features located around the highway section. Signs on posts are measured at the base of the post. Overhead signs, on bridges or gantries, are measured at the right front corner base of the supporting structure. All other locations are best estimate. |
| 18 | Guardrails | These are structures used for attempting to protect traffic from danger and are adjacent to the road surface. |
| 19 | Median crossover | The median crossover allows traffic to turn left, off the travel lanes, mostly on divided roads. May have a slow-down approach on left shoulder. Measured from start on left side of travel lanes to end on left. |
| 20 | Turnouts | This feature is to be measured from the front edge at the edge of the travel surface to the ending edge at the edge of the travel surface. These features are only on the right-hand side of the highway sections and include lead-up strips to the feature. |
| 21 | Bridge | This is a structure used by the highway section. It is not a pedestrian bridge or a railroad bridge. |
| 22 | Interchange | Grade-separated intersection of two highways/roads. |
| 23 | Junction | At-grade intersection of two or more roads. |
| 24 | Utilities crossing | Sites identified to have non-State features crossing them. |
| 25 | Infrastructure | These sites are located along the highway section and used for supporting the highway section, or some other feature of the infrastructure. |
| 26 | Ports of Entry | Located at the entrance to the State from either another State or Mexico. Should also coincide with the start or end of a highway section. |
| 27 | Border patrol check stations | These are stations located along the highway section for stopping and holding vehicles for inspection, in most cases located on the travel lanes. |
| 28 | Rest area | A location along the highway section used by the motoring public. The location is defined by the first point of possible entry to the site, to the last point of return to the traveling surface of the highway section. |
| 29 | Emergency services location | A location along the highway section used by the motoring public. The location is defined by the first point of possible entry to the site, to the last point of return to the traveling surface of the highway section. |
| 30 | Railroad crossing | This feature indicates the presence of any observable feature used by railroads to cross the highway section. |
| 31 | Drop inlet | All grated drainage structures flush with surface that can occur in the median and right-hand side of the pavement. |

The RFI software application is in an Oracle9*i*® Forms application. The application was initially developed in-house by the IT department but is currently being completed by a consultant. The application uses an Oracle9*i* Database, Oracle interMedia, Oracle9*i* Application Server, Oracle Portal, Oracle JDeveloper, and Oracle Discoverer. The RFI application also uses other key database technologies including partitioning, Oracle Recovery Manager (RMAN), materialized views, and virtual private database.

The NMSHTD database system manages more than 5 terabytes (TB) of JPEG images in the RFI application and approximately 1 million traditional (nonmedia) assets that account for approximately 100 gigabytes (GB) of storage. Using Oracle9*i* database as the image data store has simplified application development and enabled powerful indexed searches that speed route image information retrieval.

The database server runs the Oracle software in Windows 2000 on an HP server with 8 GB random access memory (RAM) and 5 TB of network storage. The application server consists of Oracle9*i* AS running on Windows 2000 on an HP server with 8 GB of RAM and 500 GB of local disk storage.

### *Road Feature Inventory Data Collection*

Data collection is performed by each district, and State patrols query all the data in their districts. New data are added as needed and identified by milepost. Among the data collected are pavement performance data such as roughness and pavement condition ratings.

The RFI system is approximately 92 percent populated. The remaining data collection activities include collection and processing of 60,000 assets and missing pieces of data, most of which are on ramps and interchanges. New data entry continues without special funding; the State will continue data collection as assets need to be repaired or replaced.

The initial cost of the RFI development was $2 million. At the time of this writing, an estimated $500,000 in additional funds would be required to complete the missing data acquisition process and implement the corrections.

In addition to electronic data collection methods, the State uses the RFI asset verification form in the field. This form is filled out manually on paper for entry back in the office. All districts have access permissions enabling them to enter data, but they cannot view data from other districts.

The RFI has been online on the NMSHTD intranet since early 2003. At the time of this writing, the system was scheduled for completion in 2005, when all collected data are anticipated to have been loaded into the database. Plans exist to integrate RFI with other State systems such as the pavement and bridge management systems so that all of State asset management systems will ultimately be supported by a single integrated database. It will also allow NMSHTC to use RFI to meet maintenance requirements and capture the value of assets for accounting purposes.

### *Road Feature Inventory Quality Assurance*

The State uses the districts to verify the data received from video, which are about 89 percent accurate. The State benchmark is set at 95 percent for accuracy, which is generally achieved as the districts correct their data. An example of insufficiently accurate data occurs when data collection for a segment of road needs to be repeated because of inadequate sunlight conditions.

The State used committees to develop the quality assurance/quality control (QA/QC) protocols, and the key district staffs were trained on the database. The State district office staff and the State maintenance engineers and managers are among the primary users.

The QA procedures include a series of survey protocols that are followed throughout every project:

- Roadways are surveyed only when there is sufficient daylight and they are dry and free of debris.
- Roadways are surveyed in a single lane to provide true, consistent data. Lane changes are avoided.

- Every effort is made to collect data during off-peak times to minimize variations in speed and visually blocked assets.
- In addition to the start and stop points along a particular roadway segment, intermediate tie-in points, such as intersecting roads or bridge locations, are noted.

At the conclusion of the field surveys, a data collection technician completes a detailed review with the raw and processed data using trend analysis, video, and, if required, field verifications. Information on pavement performance and asset is audited.

Figure 8 illustrates a sample flowchart with QA/QC checks for processing video images into the software.

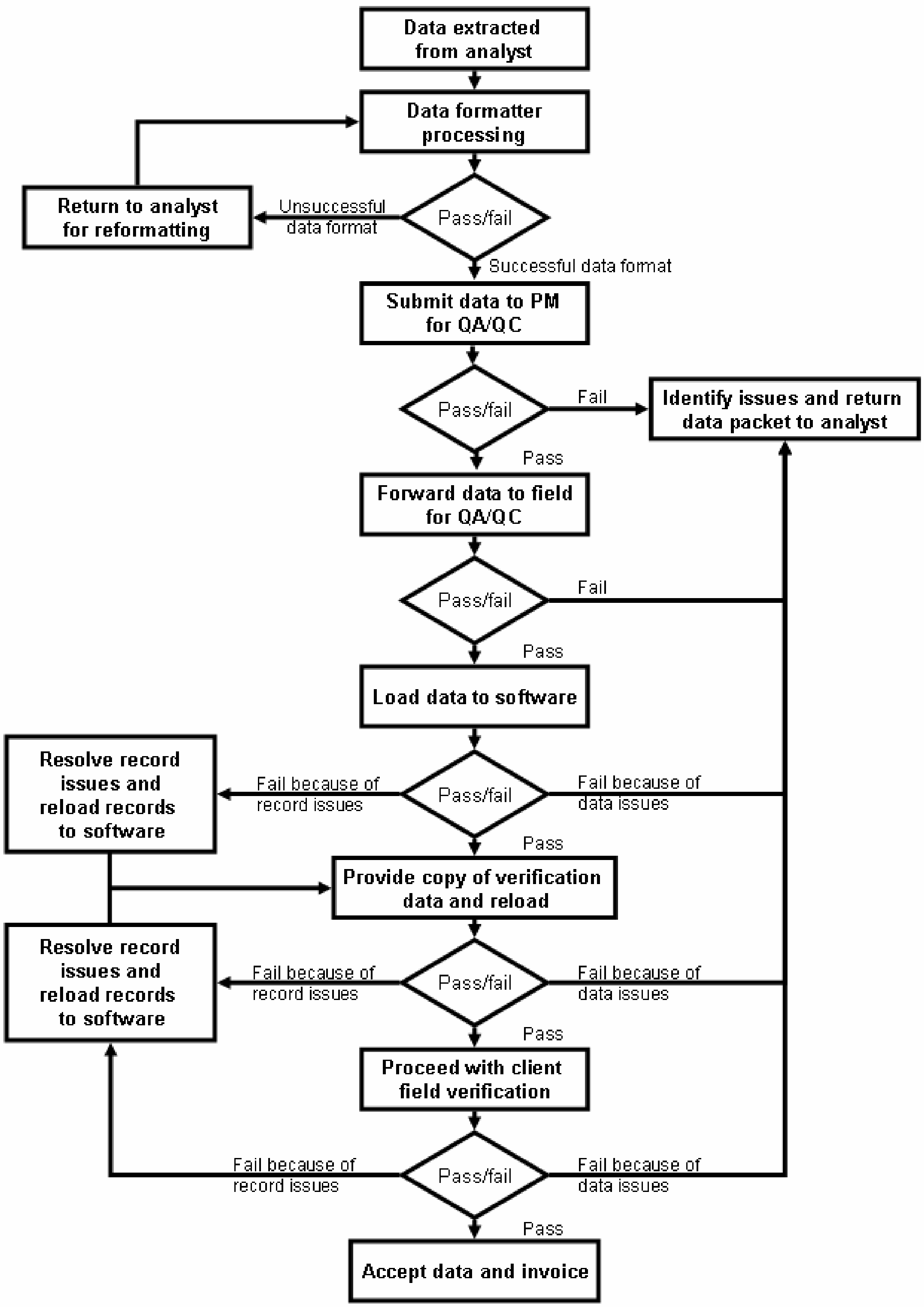


**Figure 8. Chart. Sample flowchart of RFI QA/QC checks.**

### *Highway Maintenance Management System Description*

The NMSHTD Highway Maintenance Management System (HMMS) is a collection of highway information on labor, equipment, commodities, and maintenance management processes. This system is a proprietary database, separate from the RFI. One purpose of the HMMS is to help NMSHTD use its resources in the most efficient manner to maintain the roadways for which it is responsible in the best possible condition. HMMS provides a guide to assist field personnel in managing maintenance operations effectively.

The HMMS is a tool designed to support all department maintenance personnel and help maintenance supervisors and managers make decisions. It is used for daily work reports, maintenance activities, and patrol reports. Crew members can identify their time and track their spending. The State uses the system to calculate the cost per mile for road maintenance. Other applications are for summaries to legislators and maintenance activity reports.

To instruct the many and varied users, the State in 1998 issued an internal handbook on the use of HMMS. This manual was prepared in three versions: General Office Operations, District Operations, and Patrol Operations. Each version is customized for the indicated level of operation.

The HMMS, which builds on the department's previous maintenance management system, exchanges information with three of the department's other computerized systems:

- Financial Management Information System (FMIS).
- Fleet Anywhere System, an equipment management information system.
- Payroll System.

All maintenance personnel, and particularly supervisors and managers, are involved in the maintenance management cycle of planning, organizing, directing, and controlling the work. Department personnel use the different screen sets of the HMMS throughout the management cycle. The information collected for and stored in the HMMS assists maintenance personnel in many ways. In particular, the information accomplishes the following tasks:

- Supports budget requests and special projects.
- Helps assess the need for changes in activity planning.
- Provides managers with information for decision making.
- Establishes benchmarks for comparing performance to standards.
- Passes time information to payroll, equipment usage information to Fleet Anywhere, and commodity usage information to FMIS.
- Helps evaluate contractor performance.
- Provides information to managers that they can use to identify problem areas.

HMMS is a system that manages the maintenance and budgeting activities as well as the schedule of crews. Following is a list of pertinent facts:

- HMMS features an inventory table that supports an asset count.

- HMMS is a district-based system developed with seven separate databases—six districts and the General Office. NMSHDT collects data from the districts into the central office. In the system implementation, line speed was an issue because the connection from patrols to districts was through dial-up lines. The unit continues to explore the implementation of a centralized database.
- There are 65 activities in HMMS.
- The NMSHTD has elected to develop and implement the RFI and defer, at least for now, any updates to HMMS.

NMSHTD was one of the first States to develop an HMMS, which was implemented in July 1998. The system, which was acquired from the contractor, was designed as an interactive planning, budgeting, and reporting tool. It uses Oracle and Oracle-based tools, and consolidates several documents into a single data-entry process through a data-entry system at the district patrol and crew level.

New Mexico has been using asset management systems since 1978; however, the earlier system was a mainframe program with limited planning and budgeting adjustment flexibility. The department began to consider replacing this system in 1994; however, after reviewing systems from Arizona, Utah, and Colorado, the NMSHTD determined those systems would not fully meet its needs.

HMMS project planning began in 1994. The process involved interviews with more than 100 maintenance personnel leading to development of the system requirement definition. A Request for Proposal (RFP) for the HMMS was published in March 1996. A contractor was awarded the contract, and work began in September 1996. The system was fully implemented in 1998, when it was installed statewide. The HMMS, with a project cost of approximately $2.1 million, is fully populated and functional. New Mexico is one of the few States that owns the source code for its HMMS, which allows the State to maintain the software internally without licensing or other maintenance fees.

Following the demonstrated success in New Mexico, a number of other States including Georgia, South Carolina, and Tennessee have since implemented an HMMS.

### *Highway Maintenance Management System Data Collection*

Table 4 lists the categories of New Mexico HMMS data collected.

**Table 4. New Mexico HMMS data collected.**

| Asset category | Collected |
|---|---|
| Roadway Signs | √ |
| Signals | – |
| Roadway Lighting | – |
| Supports and Structures for Signs, Signals, and Lighting | √ |
| Guardrails, Barriers | √ |

**Table 4. New Mexico HMMS data collected—Continued**

| Asset category | Collected |
|---|---|
| Pavement Markings and Treatments | √ |
| Detectors | – |

### *HMMS Current Status and Future Plans*

Plans include system upgrades when the RFI project is complete. In addition, the two databases are to merge into one database.

The integration of HMMS with RFI will figure in NMSHTD plans. NMSHTD recognizes the importance of coordinating integration planning with the IT department, and it plans for central coordination for applications and development of any future software.

RFI and HMMS integration details are not yet determined; however, HMMS has road feature components that will be replaced by RFI data.

Three interfaces—Maintenance Management System (MMS), Pavement Management System (PMS), and RFI—are also planned for the future, but these interfaces are at least 2 years away. The system currently exchanges data with three other systems:

- Equipment Management.
- FMIS.
- Human Resource Payroll System.

## Virginia Department of Transportation

The Commonwealth of Virginia has the nation's third largest State-maintained highway system (after Texas and North Carolina). This system includes approximately 91,732.61 km (57,000 mi) centerline miles of interstate, arterial, regular primary, and secondary roads, and more than 18,800 total structures, including 12,600 bridges located in 135 counties.

To make the best possible maintenance investment decisions, the Virginia Department of Transportation (VDOT) initiated a comprehensive maintenance and operations business process reengineering (BPR) effort in 1995. This effort laid the groundwork for what is now widely known as transportation asset management.

### *Inventory and Condition Assessment System*

Based on recommendations from the BPR effort, VDOT initiated the development of infrastructure decision-support systems and a large data collection program, referred to as the Inventory and Condition Assessment System (ICAS).

In 2002, the Virginia General Assembly passed legislation that requires VDOT to incorporate the principles of asset management into its maintenance and operations practices. This legislation was one of the main drivers for VDOT to develop a modernized integrated asset management system.

This new data integration strategy has enabled VDOT to make significant progress in developing decision-support tools and integrating asset management data without waiting for the details of the final Asset Management System (AMS).

A discussion of the ICAS and AMS systems follows.

**ICAS Description**

The scope of the ICAS project was to collect inventory and condition data for all roadway assets that existed within the VDOT highway fence-line boundaries. VDOT structured its approach in several phases: A pilot phase (Phase 1) to prove and fine tune the concept and procedures, a statewide implementation phase (Phase 2), and a steady state or full deployment phase (Phase 3). Additional measures used to mitigate project risk to VDOT included employing a fixed-price contract and conducting a phase-gate review or an end-of-pilot evaluation that allowed for adjustment and repricing before beginning the statewide effort.

Development of the prototype ICAS system began in 1997. A contractor provided support to VDOT with BPR work from 1995 to 1996, and then developed the initial ICAS performance and business requirements.

In 1998, following a request for proposal, VDOT selected a prime contractor and team of subcontractors. The prime contractor performed overall project management, data collection, and training. Subcontractors developed an ICAS system, performed system integration and systems training, and provided database support, GIS integration, mapping, and aerial photography analysis. The contractor also proposed a commercial off-the-shelf (COTS) data management system developed in the United Kingdom that accommodated multiple linear referencing systems. The system needed modification to fulfill the VDOT requirements.

For the pilot project, VDOT selected Fairfax, Fauquier, and Augusta counties. Combined, these three counties represent about 10 percent of State-maintained lane miles.

VDOT used video logging, GPS backpacks, and digital satellite imagery to collect data for the ICAS. Following is a list of key ICAS project deliverables:

- A complete inventory of highway-maintainable assets in three counties.
- A comprehensive data dictionary.
- A process for the consistent measurement of asset conditions.
- A statewide process for managing asset information.
- Modern information technology tools to access the information.
- Support to multiple location-reference systems.
- Statewide centerlines for the entire highway network.

ICAS has also captured a GPS-referenced digital video log along every segment of highway. These were used to develop centerline coordinates of the roadway network.

Infrastructure inventory data derived from these images are available in ICAS. The forward images, collected every 16.09 m (52.8 ft), are available in the VDOT geographic information system (GIS) and can be accessed through the VDOT intranet.

The initial concept for ICAS was to be a tool to support the AMS and provide information for statewide budgeting and planning. The goal of the completed pilot project was to collect inventory, condition, and location information for a comprehensive set of assets. A secondary goal was to store, access, and demonstrate use of this data in strategic and tactical day-to-day asset management decisionmaking.

ICAS is a PC-based client-server system based in Exor, a proprietary software system from the United Kingdom. VDOT had acquired licenses to use the system and decided not to upgrade it. VDOT is currently building the AMS and Oracle spatial database with in-house staff.

The primary users of ICAS include district maintenance staff for budgeting, planning, and scheduling work. Users were trained by the contractor and VDOT.

**ICAS Data Collection**

VDOT collected information for 42 assets, including fences, ditches, and rest areas. ICAS was a complete assets inventory, fence line to fence line. It collected asset management data in the categories listed in table 5.

**Table 5. Virginia ICAS data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | √ |
| Signals | √ |
| Roadway Lighting | √ |
| Supports and Structures for Signs, Signals, and Lighting | √ |
| Guardrails, Barriers | √ |
| Pavement Markings and Treatments | √ |
| Detectors | √ |

ICAS, now fully populated for the three pilot program counties, is being integrated with the RCA so that all data will reside in an Oracle spatial database. The database architecture is based on the NCHRP 20-27 data model. ICAS is fully integrated in the seven data categories in this study.

Other AMS tools will be integrated with the AMS Oracle spatial database, including the following systems:

- Bridge Management.
- Pavement Management.
- Virginia Operational Information.
- Plant Mix Scheduling.
- Security and Emergency Management.
- Financial Management.

### ICAS Quality Assurance

The highway network centerlines were accurate to a precision of 3.05 m (10 ft), exceeding the VDOT specifications. This accuracy was evaluated against known control points established by an independent subcontractor.

A robust QC process was implemented for the project. For the data collection, a double-blind test was conducted. After the collection was complete, random, separate QC segments were assigned to QC inspectors, who independently examined the assigned area. The results, which were overlaid on the production results to check the correlation, showed that the data collection was easily meeting contract requirements of +/− 5 percent accuracy at the 95 percent confidence level. A similar procedure was used for the image collection QC.

The QC effort during the pilot was extensive. The use of the double-blind QC procedure, while ensuring independent data verification, was also expensive and time consuming. An independent project evaluation confirmed that the data were within accuracy requirements and that the QC procedures on the number of segments to sample could be reduced.

VDOT administered a well-defined quality review process. Highway sections were selected at random and verified by onsite visual checks. Quality issues were discovered in the data collection process, operation of the software, and the data loading process. All issues were resolved and documented to VDOT's satisfaction. This review provided the basis for acceptance of the data and determined eligibility for payments to the contractor. In summary, data quality issues were not a major problem in this project.

### ICAS Current Status and Future Plans

The ICAS pilot was completed in November 2002. The three-county data collection activities are complete, but VDOT has decided not to expand ICAS statewide (it did use the concepts and knowledge learned to develop the Random Condition Assessment). Video-logged images are available on the VDOT intranet, and VDOT personnel have the capability to access data, update and add assets, and obtain reports and information from the system. The three county jurisdictions are keeping the ICAS data current.

The ICAS fixed-price costs were itemized as follows: Pavement data, $3.8 million; Phase I, $7.9 million; and Phase 2, $25 million. The actual costs of work performed, which included the accelerated Phase II centerline delivery, totaled $18 million. Statewide centerline delivery cost was $7.7 million and asset data collection cost was $4.6 million. The largest contract modifications, not counting the centerlines, were for collecting additional mileage in the pilot counties (beyond the official VDOT record), changes to the data dictionary during data collection, and delays imposed by VDOT during data collection.

The ICAS project came to administrative closure in November 2002. Having finished a review of the pilot project, VDOT executive management decided that, because of fiscal constraints, continued data collection for asset management would be addressed with in-house staff and resources. VDOT will continue to use the ICAS system and procedures adopted during the pilot to populate the required data. Project deliverables were finalized and the contract closed out.

### ICAS Useful Conclusions and Lessons Learned

One of the greatest achievements of this project was the delivery of complete statewide centerlines for all VDOT roads and highways in the Commonwealth of Virginia—more than

111,044.74 km (69,000 centerline mi). Under ICAS, the State collected information on asset inventory and inventory condition and evaluated the technology. In most cases, the tools and technologies in this project delivered good functionality and demonstrated capabilities to provide asset inventory and condition data for asset management.

The ICAS project provided VDOT with extensive information, knowledge, and documented processes. The following list summarizes a sample of the gain for VDOT:

- A comprehensive inventory of highway-maintainable assets in three counties.
- Processes for the consistent measurement of asset conditions.
- A statewide process for managing asset information.
- Modern tools and a database to access the information.
- Support to multiple location-reference systems.
- Statewide centerlines for the entire highway network.
- Eighteen field data-collection units and related software licenses owned by VDOT.
- VDOT staff gained the institutional knowledge of all the steps required to collect data and develop a highway network-based database.

An essential lesson learned was that the system used in the data collection—backpack units with voice recognition software technology—worked extremely well and enhanced safety by providing appraisers with a heads-up and hands-free capability. In addition, the inspectors were able to collect both aboveground and belowground assets and attributes and effectively assess conditions. This approach allowed an accurate and complete asset inventory and a full condition assessment.

The GPS location referencing equipment and software also were effective and enabled precise location of all assets. The system worked equally well with the field inspectors and van-based image collection technology. Having the data collected with spatial coordinates using GPS was fundamental to obtaining repeatable, verifiable, and accurate locations of assets. Raters were not required to know specifics such as official route number, milepost, or intersection and offset to locate their position. Having the assets tagged with spatial information also allowed linear referencing technologies to be used easily to integrate data from different sources in the relational database.

Despite the success of the pilot and advantages to the system, there were several reasons that VDOT opted not to proceed to the next phase and take ICAS statewide:

- *Cost*. The primary reason was the expense; it was a very expensive way to collect inventory data.
- *Video Quality.* Although the quality of the video generally was good, quality was a concern, and improvements would have been necessary.
- *Completion Delay.* Phase 1 completion took 300 percent longer than estimated, although change orders remained below 10 percent of the contract value. The pavement data portion of the project was deleted because of the exacting information required, the manual processes involved, and the state of the pavement evaluation technology at the time of the pilot. A

lesson learned was that the asset and attribute set must be determined and locked before data collection begins. In addition, this data set also should be based clearly on business needs.

### *Asset Management System*

VDOT did not select COTS software in developing its AMS because it determined that COTS software would not be cost efficient unless its specifications were close to current VDOT practices and customs. With ongoing budget constraints and the lessons learned from the ICAS experience, cost-efficiency concerns had been brought into sharp focus and played a key role in this decision.

As a result, VDOT chose to develop an AMS by revisiting the original requirements of the BPR effort. In contrast to the single COTS system envisioned in early efforts, VDOT staff divided the BPR requirements into a series of components that could be developed individually and integrated incrementally. The new AMS has six key components:

- Random Condition Assessment (RCA).
- Needs-Based Budget Request Module.
- Planning and Scheduling Module.
- Work Order and Accomplishment Module.
- Inventory Module.
- Analysis Tools Module.

Through the BPR, VDOT envisioned the management of assets through their entire life cycle: condition assessment, planning, alternatives evaluation, project development, and implementation. Decision-support tools would provide resource management capabilities such as attributing financial, equipment, and human resource investments to specific groups of assets. These systems would also enable VDOT to manage the use of its assets and provide an integrated approach for managing information such as land use permits; hauling permits; routing traffic flow; and capacity, impact, trip, and travel analyses.

Of the six planned modules, the first two are completed and the others are in different stages of development. Work on the first two components of the AMS—the Random Condition Assessment Module and the Needs-Based Budget Request Module—began in 2003. In developing these modules, VDOT followed a formal systems development process designed to provide consistency between the individual development efforts and verify that data required for the AMS are fully integrated.

The AMS, which is entirely Web-based and requires only a standard Web browser, will, according to its documentation, "enable VDOT to more efficiently and effectively manage roadway assets." Based on the results of a cost-benefit analysis of the AMS, VDOT expects a 15 percent return on investment by 2006. This rate of return is possible because the system will enable VDOT to implement its management strategies, which includes the following objectives:

- Maintain current, accurate data on inventory and condition.
- Develop statewide maintenance budget requests based on needs identified during a formal condition assessment process.

- Plan and prioritize maintenance and operations work based on an understanding of available resources.
- Improve the cost effectiveness of maintenance and operations activities.
- Determine the effect of deferred maintenance strategies on network performance and resulting needs.
- Maintain a record of work on an asset throughout its life cycle.
- Automate aspects of maintenance management function that are currently performed manually.

In addition, implementing the AMS will help bring VDOT into compliance with recommendations developed through an audit performed by the Virginia Joint Legislative Audit and Review Commission and a study conducted by the Virginia Auditor of Public Accounts.

A description of the first AMS module, the Random Condition Assessment, follows.

**Random Condition Assessment System Description**

Development work on the RCA, the first module of the current VDOT asset management system, began in January 2003.

The RCA is an inventory system with a statistically based random sampling approach for manual data collection. The RCA data are used to compute an unconstrained, needs-based budget to maintain infrastructure and VDOT assets. It includes the condition of the highway system based on extrapolating conditions of the random sample of the roadways. VDOT has the capability to extract cost information from its financial management system to support the needs-based budget analysis.

The RCA contains nonpavement and nonbridge assets and focuses on pipes and drainage, roadside, and traffic features. The protocol for districts is to collect inventory and condition data in preselected 0.161 km (0.10 mi) sections of the roadways. VDOT rates all assets within the 0.161 km (0.10 mi).

The RCA system includes a built-in help menu with definition of asset types and helpful asset pictures such as cantilever and regulatory sign types in the help menu. The menu items for signs include sign type, age, and number of panels. For each data entry, there is a comment field for the appraiser.

RCA provides a drop-down menu of choices from which the appraiser selects. For example, under signs, “post damage” and “panels missing” are among the options. Appraisers are equipped with a computerized system, either a laptop or hand-held devices, and download information daily when they return to their offices. Appraisers use standard forms, and data entry is done using a touch screen application on a PC. Appraisers are field people who, on average, hold a 2-year college degree.

On the interstate system, VDOT captured approximately 1,800 0.161-km (0.10-mi) sections out of 2,200 directional miles of Interstate roads. On primary and secondary roads, VDOT has captured 3,690 0.161 km (0.10 mi) sections. The approximate sampling rate in the RCI includes:

- 10 percent to 15 percent of interstate roads in the State.
- 3 percent to 4 percent of primary roads.
- 1 percent of secondary roads.

Using the RCA system, data for 9,000 statewide sites were collected by June 2003. The process was repeated in spring 2004.

All RCA concepts are developed on an incremental basis in-house by the VDOT Asset Management Division, which is working closely with the IT department in developing RCA. The Asset Management Division has defined the system business application and needs, and the IT department performs system development. The IT department supports the Asset Management Division, and they are well coordinated and integrated. All work is performed in-house.

RCA is an Oracle-based database system on a PC platform. The graphic user interface is built with a drop-down, menu-based system.

The primary users of the RCA data are the district maintenance staff. Other users include State and district budget managers. To train these users, VDOT formed focus groups for each district and trained the focus groups at a central location.

**Random Condition Assessment System Data Collection Efforts**

Table 6 lists the categories of VDOT RCA data collected.

**Table 6. Virginia RCA data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | √ |
| Signals | – |
| Roadway Lighting | – |
| Supports and Structures for Signs, Signals, and Lighting | √ |
| Guardrails, Barriers | √ |
| Pavement Markings and Treatments | √ |
| Detectors | – |

Relevant data from various systems are being processed and imported into a data repository. VDOT is proceeding with this work without fully understanding the details of what the target asset management system will look like. For example, the final AMS may consist of a series of individual tools, or it may resemble a comprehensive enterprise resource planning system that was once proposed. It is anticipated that if all relevant data are cleansed, normalized, and stored in a single data repository, VDOT can export data to any future system.

This strategy provides VDOT with great flexibility in designing the final AMS. The design will continue to evolve based on organizational requirements, funding availability, and emerging technologies. In the meantime, this approach has enabled VDOT to make significant progress both in developing individual maintenance decision-support tools and integrating maintenance data without waiting for the final details of the comprehensive AMS to be developed.

The RCA will be fully integrated to the other modules of the VDOT asset management system, including ICAS and two other systems:

- Bridge Management.
- Pavement Management (PMS).

The RCA general confidence level statewide stands at 95 percent. This level varies by 5 percent to more than 10 percent for various locations and asset types.

**Random Condition Assessment System Current System Status and Future Plans**

VDOT has entered approximately 20 to 25 of the 42 assets per selected 0.161-km (0.10-mi) section into the database.

In 2003, VDOT completed the first two components of the AMS: the Random Condition Assessment Module and the Needs-Based Budget Request Module. Based on the success of this initial effort, the agency proceeded to develop the Planning Module and a New Work Order and Accomplishment module. Four of its six modules have been developed at this time and are in various production and implementation stages. It is expected that the remaining modules are to be developed before the end of 2005.

Looking beyond this next milestone, VDOT will work to integrate the AMS with the Commonwealth's statewide GIS. Also, to date the scope of the VDOT AMS has been focused on maintenance and operations. It is anticipated that, when work is completed in these areas, the system may be further enhanced to provide additional decision support for the VDOT equipment program.

VDOT has learned not to rely on a single-vendor solution, but instead to pursue open standards as much as possible. The agency is interested in implementing standards that may emerge from the National Spatial Data Infrastructure Framework Project in the transportation data layer. VDOT is also coordinating with the I-95 Corridor Coalition on a regional multistate transportation network for the interstate and State routes. The department is also embracing Web-based services and views Internet map servers as an integral part of its enterprise architecture. VDOT anticipates that in the future more services will be accessed remotely through the Internet including data uploads from local handheld computers, and provide the ability to query data and applications in the field, perhaps using wireless communications. The rapid changes in technology require a flexible, open-systems approach. VDOT is conscious of the need to take small steps to take advantage of these improvements in the context of an enterprise data architecture.

VDOT has already used results from the Needs-Based Budget Request Module of its infrastructure AMS in presentations to its executive board and members of the General Assembly. Although there is much work to be done, VDOT's ability to get meaningful information into the hands of decisionmakers has solidified support for further enhancements and provided a glimpse of the power of a fully developed AMS.

The initial RCA cost for the first 3 months was approximately $300,000. The 2.5-year total RCA cost is expected to be in the low million-dollar range.

## OTHER DOT CASE STUDIES

A number of State DOTs have implemented asset management systems with various levels of integration. A selected number of these States are featured in the following paragraphs, in alphabetical order.

### California Department of Transportation

#### *Inventory Maintenance Management System Description*

In 1990, following an independent review of business processes in the Maintenance Division of the California Department of Transportation (Caltrans), it was determined that the systems were not adequate for the increasingly complex needs of the division. For example, field crews were required to enter extensive time, material, and equipment reporting data (FA83 and HM85) manually on duplicate screens. In addition, short- and long-term management information was not readily available and was often not timely or reliable.

The Caltrans Division of Maintenance planned the Inventory Maintenance Management System (IMMS) to improve internal operations. The initial phase of the IMMS project was to replace the Caltrans Maintenance Management System (MMS), a time reporting system where sign and lighting information was maintained, and its follow-on Maintenance Management System Improved (MMSI) with asset management software. The Caltrans Division of Maintenance provided expertise and input to modify the software product to suit the needs of its users.

IMMS was tailored to meet the specific needs of the division. Following is a list of tasks the IMMS team accomplished:

- Identified business needs and determined how IMMS could best accommodate them.
- Configured (or customized) IMMS to meet those needs.
- Reviewed business issues such as special designations and production units.
- Loaded data into IMMS.
- Developed training and implementation materials to make the transition from MMS/MMSI to IMMS and the new way of doing business as easy as possible.
- Used resources from Headquarters, Information Systems and Service Center, districts, regions, and contractors to work together for a successful implementation.

IMMS is a COTS software developed by a California company. After a competitive bidding process, the State awarded the development of IMMS in 1996. The general specifications of IMMS were set by the Department of Information Technology, and a computer application was selected as the core of IMMS.

The IMMS system is mostly based on reports on time tracking and individual assets, and it has limited built-in reporting. IMMS contains some cost data but comprises mostly individual data elements.

The key function of the Caltrans Maintenance Division is to perform work activities on Caltrans-maintained assets such as lights, signals, bridges, landscape areas, and the roadway. The Caltrans IMMS is designed to track time, material, and equipment. One feature of the system captures how much time the crew worked on each job. Work performance items listed in IMMS include day labor work order, input/output, and inventory order. IMMS is designed to give supervisors access to detailed information about each asset, where it is located on the roadway, and work being performed on the asset.

Following is a list of the planned benefits of IMMS:

- Provide the Maintenance Division with access to real-time data.
- Allow more effective monitoring and control of materials by improving the accuracy of data that are entered and stored.
- Make it easier to generate reports, enabling staff to receive inventory reports instantly instead of filling out a request and waiting for the data.
- Eliminate the need for users to enter duplicate information on multiple systems.
- Reduce the amount of time users spend on administrative tasks such as re-creating information that has already been collected.
- Make it easier for users to effectively coordinate large projects involving multiple crews.
- Allow users to easily determine where equipment is located and who is using it.
- Provide a central repository for information at all levels, better enabling headquarters to justify the need for more resources.

IMMS comprises three primary elements. The first element is the computer program at the core of IMMS. All users access this program to create work orders, enter time and work information, adjust working stock, and view information about IMMS assets.

The second element is the IMMS database. When a user views information or enters data into IMMS, the data are accessed directly at the IMMS database located at headquarters in Sacramento. All information entered is stored in this database. Users throughout the State can input information directly into the IMMS database through one of 11 servers.

These 11 servers and a Citrix® access program work together to form the third element of IMMS. Citrix directs all information moving to and from the database to one of the servers. IMMS uses multiple servers to handle high volume periods, when supervisors throughout the State may be accessing IMMS at the same time. This helps in entering all information updates quickly and providing easy access to the information.

A key feature of the IMMS is the Roadway Feature Viewer. The IMMS Roadway Feature Viewer (Viewer) provides a convenient way for supervisors to scrutinize information about a roadway; for example, supervisors can easily see the locations of assets along the roadway and either view information about work being performed on an asset or create a work order for the asset. In addition, they can view the location of work being performed on a portion of the roadway and have access to information about the roadway itself, such as the number of lanes or speed limit.

A supervisor who is planning work for a specific section of roadway can check the Viewer to see if other work is being performed at or near the location. This alerts the supervisor to conflicts or help to coordinate the sharing of resources more easily.

The IMMS implementation was planned for three phases:

- *Phase 1, Go-Live Preparation***.** In each district, the IMMS team planned for the implementation in a district by conducting several preparation activities. The IMMS team worked side-by-side throughout implementation with a team of district staff that provided expertise to help a smooth transition to IMMS. These efforts included:
  - Meetings to kick off the district's implementation were held to provide information to users about IMMS, its benefits, and what users can expect during implementation.
  - Workshops with users to explain how daily business practices will change with IMMS. During these workshops, adjustments to the new business practices were made so that they meet the needs of users in each district.
  - A readiness assessment, or survey, was conducted before implementation to ensure that all of the activities necessary for a successful implementation were indeed completed in the district and that IMMS was ready to go live.
  - Installation of the IMMS software program on users' computers. The software was also tested to ensure it was working properly.
- *Phase 2, Go-Live Phase.* The IMMS team performed the implementation and verified that IMMS ran smoothly. The IMMS team worked with each supervisor to conduct a working stock inventory to verify that the IMMS parts count was accurate and updated. In addition, users, primarily superintendents, supervisors, lead workers, and select headquarters, district, and region staff, were trained before implementation. To the extent possible, users were trained in groups based on their jobs (such as regional staff or superintendents), and crew type (such as electrical or landscape supervisors). Superintendents, supervisors, and lead workers were trained together during a 4-day class; district and regional staff were combined for 2 days of training; and a group of headquarters staff were to receive 2 days of training during pilot implementation.
- *Phase 3, Post-Implementation Phase.* The IMMS team supported users in each district. After implementation, users in the district who were designated IMMS experts, or super-users, were available to provide ongoing support to other users in their district. A dedicated IMMS help desk was also made available during and after each district implementation.

### *Inventory Maintenance Management System Data Collection*

IMMS is an Oracle-based system. The software selection was based on department policy to use Oracle and Oracle-compatible software so that different systems can interchange data.

All electric power systems are in IMMS, including luminaries, signals, ramp meters, flashers, cameras, message signs, all lighting, tunnel lighting, and loop detectors. Table 7 lists the categories of California IMMS data collected.

**Table 7. California IMMS data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | – |
| Signals | √ |
| Roadway Lighting | √ |
| Supports and Structures for Signs, Signals, and Lighting | – |
| Guardrails, Barriers | – |
| Pavement Markings and Treatments | – |
| Detectors | √ |

Although data entry is planned, Caltrans has not completed it because of the State's current budget constraints.

Caltrans recognizes the need for coordination between IMMS and other systems such as the Pavement Management System and Bridge Management System, but is not budgeted for activities soon.

The department is maintaining the previous generation of its asset management system (MMS) until IMMS is fully populated. During the transition, the State will maintain two parallel systems, which are anticipated to be in existence for many years.

### *Inventory Maintenance Management System Quality Assurance*

The IMMS team tested the application software and IMMS data to verify that IMMS meets the needs of all users. Following are descriptions of the types of testing performed:

- Functional testing to verify that the application software works correctly.
- Performance testing to verify that IMMS can handle many people using it at the same time.
- User acceptance testing to determine if IMMS meets the business needs of the Maintenance Division.
- Integrated systems testing to determine if the functions a user would perform in a typical day, including interfaces with other systems, work properly.

### *Inventory Maintenance Management System Current Status and Future Plans*

The final phase of IMMS implementation concluded in June 2003. All the districts are now using the software.

There is no allocated budget for IMMS future development, although one of the future development plans for IMMS includes wireless data entry for inventory.

Following is a list of some of the needed IMMS improvements identified by the Caltrans Maintenance Division:

- Set report query rights for the staff.
- Improve the reporting system.
- Make the system more accessible to users.
- Improve help desk service.

### Florida Department of Transportation

The tremendous volumes of data that the Florida Department of Transportation (FDOT) is responsible for keeping track of and regularly updating led to the development of a tool to more easily manage the department's asset information. The Roadway Characteristics Inventory (RCI) System was created in response to this data management need. The district and central offices within the FDOT maintain the RCI, which is the largest department database with more than 1 million records. The database is updated daily to reflect the most current information available.

#### *Roadway Characteristics Inventory System Description*

The Roadway Characteristics Inventory (RCI) system is a computerized database of physical and administrative data related to the roadway networks that are either maintained by or are of special interest to the FDOT. The RCI also contains other data as required for special Federal and State reporting obligations. Some of the specific items that the RCI database includes are roadway signs, traffic signals, pavement markings and treatments, guardrails, and barriers. The system currently tracks assets in the Department of Maintenance and Traffic Operations Control, including roadway lighting, structural supports, and detectors.

RCI uses the following data categories:

- *Roadway Identification.* The road system designation in RCI is based on an eight-digit identifier called a Roadway ID. Mile points associated with a Roadway ID represent specific locations or physical points on the road. Mile points typically start at the Begin Mile Point with a value of 0.00 and accumulate to the End Mile Point of the Roadway ID.
- *RCI Roadway Features***.** A feature is a general grouping of physical attributes of a roadway identified by a unique three-digit number and name. Different types of features include administrative, geometric, and operation and maintenance data, and the types may refer either to points or extended lengths.
- *RCI Roadway Characteristics.* A characteristic is a specific element of the roadway identified by a unique name up to eight characters long. Roadway characteristics can be thought of as components of a roadway feature, such as shoulder width and shoulder type for a shoulder feature. Besides these values, characteristics can include information such as the units of measurement or distance from centerline.

The primary users of the RCI include the FDOT Traffic Operations, Pavement Management, Maintenance, Work Program, Safety, and Statistics Departments. Limited access is also given to department consultants. Access for consultants to the RCI database requires authorization from the various division managers in FDOT.

FDOT offers training classes for internal use of the RCI database every several months when a number of new employees are qualified for the training and express an interest in taking it.

***Roadway Characteristics Inventory System Data Collection***

Table 8 lists major asset data categories collected for the RCI database.

**Table 8. Florida RCI data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | √ |
| Signals | √ |
| Roadway Lighting | √ |
| Supports and Structures for Signs, Signals, and Lighting | √ |
| Guardrails, Barriers | √ |
| Pavement Markings and Treatments | √ |
| Detectors | √ |

Each feature listed above has multiple characteristics such as pavement index, condition, and roughness. The database population depends on the availability of information from the field, not RCI system limitations. FDOT has entered all available data for the RCI system in the three data categories—identification, features, and characteristics.

At the time of this writing, FDOT was in the process of implementing a Web-based system for accessing the RCI database. Access is limited to mainframe use onsite at FDOT offices statewide and, although the data will continue to reside on these mainframe computers, remote access over the Internet will be available for authorized individuals.

The database is maintained by department computer personnel, with access by specified personnel from the district and central offices. At this writing, PCs are used as terminal emulators, but following the anticipated launch of the Web-based access system, laptops will be used for Web access. The system will be capable of allowing users to view data directly or download to various spreadsheets or database software.

***Roadway Characteristics Inventory System Quality Assurance***

A quality control plan for the RCI data is administered by the district office and reviewed by the central office. Quality assurance reviews (QARs) are conducted by the Transportation Statistics Office (TranStat) staff working with the district office. QARs are intended to monitor activities and demonstrate compliance with approved department policies, procedures, rules, guidelines, and standards.

TranStat conducts QARs in each district at least biennially to determine compliance with the critical requirements identified in the General Interest Roadway Data Quality Assurance Monitoring Plan defined in the District QC Plan for Highway Data Reporting.

The district assists TranStat personnel in conducting QARs by providing the following resources:

- A licensed driver and a vehicle that can accommodate a minimum of four people and is equipped with a distance-measuring instrument.

- An additional person knowledgeable in the program being reviewed to accompany the team and answer questions. This person may also serve as the additional driver, if an additional vehicle is required.
- Documentation on the roadways and counties selected for review including construction notices, highway performance monitoring system (HPMS) sample locator maps, inventory schedules, county section number key sheets, and straight line diagrams.

After the field review is completed, TranStat staff conducts an exit interview with the district secretary or designee and other personnel. TranStat uses district feedback and review team observations and findings to determine the effectiveness of data collection processes to make recommendations to improve district or TranStat processes, or both. When requested, and with district input and support, the TranStat staff develop recommendations for appropriate process-oriented remedial actions in areas of noncompliance.

TranStat tracks the district's Action Plan and conducts follow up field and office reviews on areas of noncompliance. In addition, TranStat provides details of discrepancies found during the QAR within 30 calendar days of the exit interview. The details of the discrepancies include documentation of the deficiencies by roadway identification and a milepost range.

### *Roadway Characteristics Inventory System Current Status and Future Plans*

FDOT has populated the database with all available data for the RCI system. The database is updated daily when the department obtains new or modified information. The RCI database resides on the department mainframe computer system, and it is maintained by department computer personnel from the district and central offices.

The FDOT Office of Information Systems (OIS) is in charge of operating and maintaining the database with assistance of contractors directed by OIS staff.

The cost of operating and maintaining the RCI database is difficult to estimate because it has been ongoing for several years and continues with frequent updates.

## Georgia Department of Transportation

The Georgia Department of Transportation (GDOT) has several asset management systems in place including the Traffic Signal Inventory Program, Highway Sign Management System (HSMS), and the Highway Maintenance Management System (HMMS), which is similar to the MMS being developed by the Tennessee DOT discussed later in this chapter. The GDOT systems are not integrated.

As in many States, fiscal constraints play a significant role in the ability of GDOT to complete its asset management systems using integrated databases or technologically current data collection methods. As a result, GDOT must move incrementally toward the initial effort to populate its databases with current asset information, let alone proceed with systems integration.

### *Highway Sign Management System Description*

GDOT HSMS is a comprehensive database capable of storing detailed information about State DOT signs. The system, built by a contractor, is fully developed but not populated with data.

The system features include barcoding, stock inventory, and roadside inventory options. A user-friendly menu bar is designed to access the modules. The File, Reports, and System Administration options on the menu bar include drop-down menus of more options.

When a new sign is manufactured, a barcode label containing all the information describing the sign is printed and affixed to it. For old signs, a generic barcode label can be printed that only contains a unique barcode key. The information about the old sign is requested when the sign is scanned into inventory. Following is a list of designated fields in the HSMS:

- Height in inches.
- Width in inches.
- Size in square feet.
- Fabrication date.
- Warranty date.
- Cost.
- Substrate material.
- Sheeting manufacturer.
- Legend sheeting type.
- Background sheeting type.
- Legend color.
- Background color.

In the case of special signs, the following data are collected for each line of text on the sign: line, text, font series, font size, size in inches, legend colors, background colors, and application method.

Data screens on the roadside inventory all share certain features, including the top portion of the screen, which displays the assembly information, and the buttons on the left side of the screen, which allow the user to navigate to and from five data screens—assembly location detail, assembly inspection, sign position, sign detail, and sign inspection.

Figure 9 is a screen capture of a sample assembly detail screen. This is the introductory screen used for the roadside inventory data screens because it is the first screen a user sees when selecting an assembly.

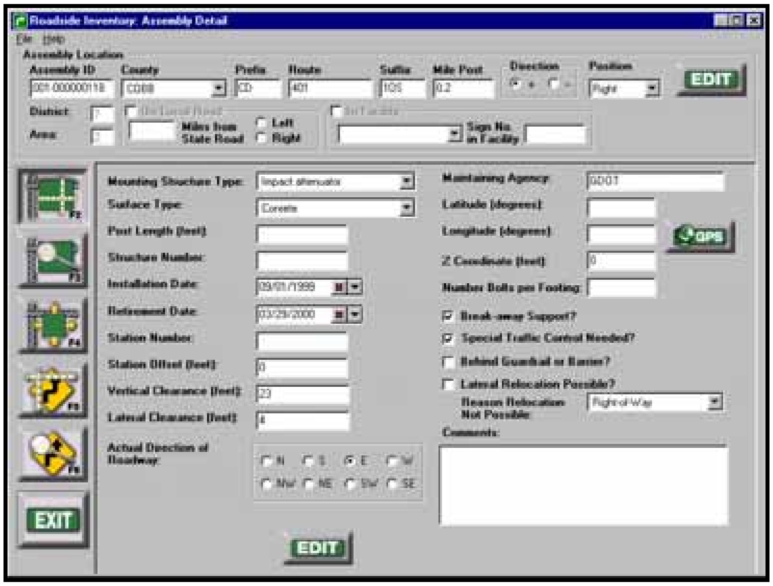


**Figure 9. Screen capture. Georgia DOT HSMS sample data screen.**

### *Highway Sign Management System Data Collection*

Table 9 lists the categories of Georgia HSMS data collected. The database includes location of sign, GPS, milepost, location on left or right side of the road, type of sign, height, lateral offset to the bottom, fabrication, and installation date.

**Table 9. Georgia HSMS data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | √ |
| Signals | – |
| Roadway Lighting | – |
| Supports and Structures for Signs, Signals, and Lighting | – |
| Guardrails, Barriers | – |
| Pavement Markings and Treatments | – |
| Detectors | – |

The HSMS is completely in place, but is not populated with data, nor is it correlated to HMMS.

### *Highway Sign Management System Current Status and Future Plans*

The HSMS is fully developed. GDOT intends to develop a plan to populate the database, but the process will be incremental. Fiscal constraint is the primary reason the sign data have not been entered in this completed system. Because the State is moving to a digital photo log system, the HSMS could be tied to a GIS if funding permits.

## Maryland State Highway Administration

The Maryland State Highway Administration (MDSHA) does not use a single, integrated, computerized database for all roadway characteristics. There are a number of databases kept by various operating divisions to inventory and report on the assets under their responsibility. These databases are integrated as necessary through a shared route system based on the roadway inventory used for internal and Federal reporting requirements. The route system uses a standard key and mile points relating each of the ancillary systems to it and to one another.

### *Highway Management Information System and Roadway Route System Description*

The data source for roadway information is the Highway Management Information System (HMIS) maintained by the database management section of the Highway Information Services Division. Roadway data are collected by inventory crews and integrated with data supplied by local county governments. The information gathered and maintained by the system is used for reporting and mapping support within and outside MDSHA. It is also the information base from which the intelligent GIS roadway route system was developed and is maintained. The HMIS also supports reporting for the Highway Performance Monitoring System (HPMS).

By facilitating the reporting and map display of their data on a graphical roadway map, the GIS Roadway Route System serves as an integrating function for databases maintained by Bridge, Pavement, Signal Operations, Accident Reporting, and Project Planning divisions.

The HMIS is updated as requested data are received from county governments and verified as part of the inventory process. The system resides on a Windows 2000 server running an Oracle database, as are the large databases maintained by other divisions. Smaller databases are maintained on Windows 2000 workstations running Microsoft® Access. The GIS Roadway Route System is also maintained on a Windows 2000 server running Oracle.

The GIS Roadway Route System is designed to provide linear referencing capability using single line work for all Interstate, U.S., Maryland, and major county routes based on the FHWA functional classification; that is, all roads are referenced except for urban and rural local roads.[(4)]

The State is responsible for the maintenance of the core systems that support and integrate the data for the operating division; that is, the HMIS and the GIS Roadway Route System. Contractors are used to aid the development of new applications and also perform some continuing daily functions such as roadway inventory and cartography.

Users of the various systems integrated by the GIS Roadway Route System are the direct users, who update and maintain the system application databases, and the indirect users, or customers, who use the data from these databases in conducting MDSHA business.

The Roadway Inventory (HMIS) supports the GIS Roadway Route System and integrates data from the other systems. The GIS Roadway Route System, in turn, supports a GIS Data Viewer application that facilitates map display, printing, and reporting of HPMS. Additional elements supported include pavement, bridge, accident, signals, and highway needs inventory data on more than 450 desktops across the State.

The GIS staff continually seeks opportunities to facilitate the use of the GIS Roadway Route System as an integrating tool, and staff members serve as internal consultants to any department or individual with a need to display or report on data that can be spatially enabled. They also provide as-needed training for the GIS Data Viewer.

### *Highway Management Information System Data Collection*

The HMIS master file contains records to store each intersecting feature by route number and mile point. Features include, but are not limited to, intersecting routes, municipal and county boundaries, bridges, cultural features, some private roads, and road ends and cul-de-sacs.

The Universe file contains roadway section data designated by route number, beginning mile point, and section length to support internal reporting and HPMS requirements. Data such as median width and type, number of lanes, shoulder type and width, pavement type, average annual daily traffic (AADT) and other characteristics are maintained.

### *GIS Roadway Route System Data Collection*

This system contains graphical line work and attribution to support the use of linear referencing of other data sets to the roadway base. The system line work is based on intersection-to-intersection, and it is calibrated using intersecting roadway feature mile point measures, as determined by roadway inventory data from the HMIS.

Databases relate to the GIS Roadway Route System using a standard key:

- *HPMS.* Section data from the universe portion of the HMIS are mapped and reported using the route system.
- *Accidents.* Detail and summary statistical data for accidents are reported and mapped. Information such as accident time, weather conditions, roadway conditions, and other accident characteristics are made available on a controlled, need-to-know basis.
- *Bridge.* This database maintains inventory and analytical data on bridges and smaller structures for interested users within MDSHA throughout the State.
- *Pavement.* Roadway pavement characteristics and ride quality data (collected by the Pavement Division) are maintained for use by other divisions of MDSHA, such as Project Planning and Highway Maintenance.
- *Highway Needs Inventory.* This database provides a tracking and long-term look at roadway projects under study but not yet funded.
- *Signals.* An ongoing inventory of traffic control devices and their attributes can also be mapped and related to other databases through the GIS Roadway Route System.

Table 10 lists the asset categories of data collected in the Maryland GIS Roadway Route System.

**Table 10. Maryland GIS Roadway Route System data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | – |
| Signals | √ |
| Roadway Lighting | – |
| Supports and Structures for Signs, Signals, and Lighting | – |
| Guardrails, Barriers | – |
| Pavement Markings and Treatments | – |
| Detectors | – |

All of the databases mentioned are mature and have been in use for a number of years. The HMIS in particular has evolved from a paper system through several generations of computer system technology. Most of the other systems have evolved in a similar way.

The HMIS recently completed a reengineering process that has introduced improved technology to provide better data and more efficient operation. Many of the changes were in direct response to the needs of the GIS Roadway Route system to support the increasing needs of its users and the other divisions who maintain data sets for their own information requirements. The GIS section has a Web-based application to supply roadway video-log images using a map-based interface. The application is being enhanced to provide aerial photography or roadway video for a specific set of project limits through an enhanced map and textual interface.

All of these database applications reside on Windows 2000 servers or workstations and Oracle 9*i* or Microsoft Access 2002, depending on hardware platform. The applications are accessed using client-server technology; however, several Web-based applications are in development, and others are in the planning stage.

### *Highway Management Information System and Roadway Route System Quality Assurance*

As new roads are added to the public highway system, roadway inventory information is supplied by local governments. State highway personnel then field-verify the information, collecting various attribute information and GPS data. After this field data are returned to headquarters, aerial imagery is used to QA the GPS data. QA is also performed by offices that maintain other data sets such as bridges, pavement, traffic devices, and accidents.

### *Highway Management Information System and Roadway Route System Current Status and Future Plans*

A project has been undertaken to enhance the GIS Roadway Route System to include all roads in the State, including all local roads, ramps, collector-distributors, auxiliary lanes, and both sides of divided highways. This project required lengthening the standard identification key field from 13 to 36 characters to accommodate the required additional coding.

The GIS Roadway Route System enhancement, including divided highways, collector-distributors, and all locally maintained routes, is proceeding with the cooperation and help of many county governments. This effort will produce a route system that provides location services based on linear referencing and address geocoding to all State departments and county governments as well.

The various systems have been in place for many years and have undergone much change. Cost data for ongoing maintenance and periodic enhancement are unavailable.

### *Traffic Structure Inventory Inspection and Maintenance System Description*

After reviewing asset management systems in use at VDOT and the Delaware Department of Transportation, the MDSHA Office of Bridges determined those systems could not meet its needs without reworking. MDSHA contracted with consultants to provide an automated structure inventory system that could also track maintenance and inspection activities. This automated system is the Traffic Structure Inventory Inspection and Maintenance (TSIIM) system.

The data fields and structure components captured by the TSIIM system were determined after numerous meetings and reviews of the MDSHA DOS-based database, its paper inventories, and inspection forms previously filed.

TSIIM comprises three components: TSIIM Inspector, TSIIM Manager, and TSIIM Online. TSIIM Inspector is written on a desktop database platform (Microsoft Access with a Visual Basic front-end) for portability. The TSIIM Inspector consists of modules for Sign Structures and High Mast Light Poles with development of modules for Bridge-Mounted Signs and Signals planned. TSIIM Manager will be developed later on an Oracle platform, and it will have the ability to check-in and check-out structures for inspection and compare history. TSIIM Online will be developed to allow those interested in traffic structure inventory or its inspection data to search, review, and print a limited set of information about the structures on the MDSHA intranet.

The TSIIM is run on Intel® processor-based PCs using a Microsoft Windows NT/2000/XP platform with a Crystal Reports® Runtime engine and Visual Basic Runtime libraries.

The primary users of TSIIM are in the Structures Team of the Traffic Engineering Design Division. A training session was arranged to train teams who are inspecting structures and populating the database.

### *Traffic Structure Inventory Inspection and Maintenance System Data Collection*

Table 11 lists the categories of Maryland TSIIM data collected.

**Table 11. Maryland TSIIM data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | – |
| Signals | – |
| Roadway Lighting (high mast only) | √ |
| Supports and Structures for Signs, Signals, and Lighting | √ |
| Guardrails, Barriers | – |
| Pavement Markings and Treatments | – |
| Detectors | – |

Data for nearly 250 of the 2,500 traffic sign structures (cantilever and overhead) have been entered in the system. All of the data will be populated by 2008.

At present, inspectors input their own data sets into the system. The data reviewer at MDSHA calls up those data sets by double-clicking on them. The Structures Team reviews the TSIIM data before a data set is populated.

### *Traffic Structure Inventory Inspection and Maintenance System Current Status and Future Plans*

The system is being used by several consultants under a 5-year system inspection contract. The consultants' efforts will be assisted by the use of data collected by the State field inspection staff.

Integration between data sets and historical data support is planned for when the TSIIM Manager is developed. Other plans are to integrate with the GIS base maps maintained by the MDSHA Highway Information Systems Division and to integrate with the MDSHA intranet, allowing limited data query and printing capabilities.

Future development includes upgrade to an extensible generic asset inventory, inspection, and maintenance data management program. The development will integrate data from all inspection teams. Further enhancement will allow for the check-in and check-out of this data for repeat inspections and provide historical data review and optimal fund allocation analyses.

For TSIIM Online, an intranet interface to the inventory and inspection data for general use within SHA will be further developed. These components will also interface with GIS.

## Minnesota Department of Transportation

### *Automated Facilities Management System Description*

The Minnesota Department of Transportation (Mn/DOT) Automated Facilities Management System (AFMS) is used to track the Electrical Services Section maintenance activities. AFMS also coordinates requests for materials and work produced by the Mn/DOT Metro Division and the eight district traffic offices overseen by Mn/DOT. The AFMS is limited to traffic signals and other electric/electronic facilities that Mn/DOT owns, operates, or maintains.

The AFMS is used by the districts to order equipment, maintain the history of maintenance calls, summarize work orders, and keep track of the maintenance activities at each intersection. AFMS is also used as the system of record for State One Call (Miss Utility) verifications.

The software enables the districts to enter a work request that includes a summary of the work order, work order requirements, assigned employees, vehicle use, components, fiber test, and loop test.

The AFMS was developed by Mn/DOT more than 10 years ago with the goal of cost effectively and efficiently managing the asset classes covered by the system. The original software was an MS DOS-based system, which has since been converted to MS Windows. AFMS project challenges have included the implementation and user friendliness of the software.

The primary users of the AFMS are the districts. User training for the rollout of AFMS V2.0 was conducted during October 2002 at the Mn/DOT Central Shop in Fort Snelling, MN.

Mn/DOT completed a pilot study of a video-based system in 1999. The Sign Inventory System captured signs and guardrail data in the Rochester District, one of the eight districts under Mn/DOT responsibility.

The video scanning was performed using proprietary software. Mn/DOT decided not to pursue the project or expand it statewide because of concerns over the cost of development and maintenance for the software. The pilot study cost for partial data collection was approximately $167,000. In addition, the software, developed in 1999 was not Y2K compliant.

### *Automated Facilities Management System Data Collection*

Table 12 lists the data categories that are collected by AFMS.

**Table 12. Minnesota AFMS data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | – |
| Signals | √ |
| Roadway Lighting | √ |
| Supports and Structures for Signs, Signals, and Lighting | – |
| Guardrails, Barriers | – |
| Pavement Markings and Treatments | – |
| Detectors | – |

All signals and lighting systems on State highways are in the database, but, the AFMS is not integrated with the other Mn/DOT asset management systems.

A contractor was retained to develop the customized AFMS V2.0 software. AFMS is an Oracle client-server database application that is run on MS Windows-based software. The system was originally an MS DOS-based system designed as a two-tier client-server application to operate on Mn/DOT in-house local and wide area networks. The IT department has managed the conversion to MS Windows.

The hardware is based on a database server with Oracle Forms running on an existing runtime environment on client machines. The client operating system is NT/2000/XP, and the server is non-OS specific.

#### *Automated Facilities Management System Quality Assurance*

A QA plan was filed as part of the standard project deliverables for AFMS V2.0. This document, available on request, describes the participants and procedures.

#### *Automated Facilities Management System Current Status and Future Plans*

The AFMS is fully populated, and new data entry is performed manually. No major enhancements are planned. The estimated cost of the current production system is $191,800 for AFMS V2.0.

### Tennessee Department of Transportation

Tennessee Department of Transportation (TDOT) conducted a survey in February 2000 to research the available asset management systems in other DOTs. The results of the survey were used in developing the plans for the State's next generation asset management system. A summary of the State survey results can be downloaded from the TDOT Web site at http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_operations/maintenance/MMS.htm

TDOT has two asset management systems in place:

- Tennessee Road Information Management System (TRIMS).
- Maintenance Management System (MMS).

Data reside on TRIMS as the first level of the asset management system. The MMS is the next level of the asset management system, which is under development.

#### *Tennessee Road Information Management System Description*

TRIMS is an enterprise transportation database owned and maintained by the TDOT, and it was developed to improve cost effective and efficient asset management. The TRIMS Oracle database contains information on each public road in Tennessee, totaling more than 136,794 km (85,000 mi) of roadway. The PowerBuilder® interface allows users to query inventory data, digital photographs, road mileage, documents, digital plans, and scanned documents. TRIMS also has a graphic interface, which offers map-based queries and displays information on maps, providing a more effective tool for planners and engineers.

TRIMS functionality supports the following Federal and State mandates for TDOT:

- HPMS.
- Annual Bridge Report.
- County local bridge grant program.
- High crash location listing.
- Roadway deficiency studies.
- Railroad grade crossing priority listing.
- GASB 34.

TRIMS was developed by a transportation asset management and visualization products company in Huntsville, AL. The TRIMS system in TDOT headquarters runs from an application server configuration. In the regions and districts, TRIMS runs from a client-server configuration. The software is Oracle-based software running on Windows NT and Windows 2000 Professional.

The TRIMS project experienced excellent coordination and support with the IT department. TDOT has assessed the common tools for design, development, and project tracking as being very useful.

The system is in use by field staff to plan and execute work and by office staff to manage needed maintenance and develop analyses in support of budget requests. TDOT has developed an internal guide to the TRIMS system to familiarize users with the TRIMS hardware, network, operating system, database, and intranet/Internet connections.(5)

### *Tennessee Road Information Management System Data Collection*

Table 13 lists the categories of TDOT TRIMS data collected.

**Table 13. TDOT TRIMS data collected.**

| Asset Category | Collected |
| --- | --- |
| Roadway Signs | √ |
| Signals | – |
| Roadway Lighting | – |
| Supports and Structures for Signs, Signals, and Lighting | – |
| Guardrails, Barriers | √ |
| Pavement Markings and Treatments | √ |
| Detectors | – |

TRIMS features the following information:

- Accidents.

- City boundaries.
- County boundaries.
- Elevation alignments.
- Geometrics.
- Horizontal alignment.
- Maintenance features.
- Maintenance inventory.
- Railroad crossings.
- Rivers.
- Road history.
- Road segments.
- Road descriptions.
- Route features.
- State boundaries.
- Structures.
- Surface conditions.
- Traffic.
- Urban boundaries.
- Vertical alignments.

The State plans to integrate TRIMS into the MMS. TRIMS is compatible with the Bridge Overhead Structure Database, but it is not integrated with other State systems such as the Construction Management System (CMS) and the TDOT financial accounting system.

### *Tennessee Road Information Management System Current Status and Future Plans*

TRIMS is a fully functional database. In the future, TDOT wants additional support functions to improve access to TRIMS through the Web. TDOT requires the regions to be able to contact TRIMS through the intranet concerning upgrades on route openings, route realignments, and data issues.

### *Maintenance Management System Description*

The objective of the MMS is to provide TDOT with a sound, cost effective, solution that can integrate upward to manage maintenance expenditures, labor, equipment, and materials. The intent is for MMS to provide efficient use of funds and budget planning. It is anticipated that MMS can be developed and implemented by using existing applications and customizing the integration of these products with each other as well as with existing and proposed IT infrastructure.

The MMS has three primary goals:

- Improve the effectiveness of inventory tracking to streamline associated costs.
- Provide a system of measuring and monitoring budget and performance.
- Provide a system to develop yearly work plans for measuring manpower and equipment needs.

In May 2002, TDOT selected a contractor to develop and implement the MMS for Tennessee. TDOT procured the MMS to provide a single-source data entry point, primarily used by middle managers, to automatically transfer information to and from other internal databases such as the Tennessee financial system and TRIMS.

The following goals and objectives were identified for the maintenance management process:

- Develop and analyze yearly work plans to project manpower, equipment, and material needs.
- Provide a level of service throughout the State highway system that is consistent and meets the overall funding goals.
- Budget equipment and materials based on estimated work effort.
- Provide for work scheduling.
- Track the work effort of the various maintenance work units.
- Provide for the tracking of contract maintenance projects.
- Compare contract versus in-house unit cost.
- Support managerial decisions.
- Provide for a single data entry point.
- Provide an ad hoc reporting tool to satisfy administrative queries.
- Measure preventive maintenance.

Maintenance management systems have been used by highway departments since the early 1970s to assist in the planning, scheduling, and tracking of maintenance work. Formerly, these systems were mainframe applications; however, over the past several years, many advances have been made in this field. These systems are now being converted to client-server applications that are integrated with many other systems to form a network capable of transferring information instantly and in many cases, eliminating the duplication of work.

The TDOT approach to analysis of the Functional Requirements Document (FRD) was accomplished in several phases:

- Determine the MMS functional requirements.
- Perform subject matter expert interviews.
- Follow up joint requirements definition.
- Conduct a best practices survey.

This approach was developed to optimize TDOT's ability to collect and document its MMS requirements.

### *Maintenance Management System Data Collection*

Table 14 lists the categories of TDOT MMS data collected.

**Table 14. TDOT MMS data collected.**

| Asset Category | Collected |
|---|---|
| Roadway Signs | √ |
| Signals | – |
| Roadway Lighting | – |
| Supports and Structures for Signs, Signals, and Lighting | – |
| Guardrails, Barriers | √ |
| Pavement Markings and Treatments | √ |
| Detectors | – |

The MMS is in the development, and it is not populated. The MMS was initially designed to interface with the following existing and proposed systems:

- TDOT financial accounting system—STARS and TDOT STARS.
- TDOT intranet.
- State of Tennessee Web pages.
- Geographic Information System.
- Document Management System (DMS).
- Executive Information System (EIS).
- TRIMS.
- CMS.
- Program, Project and Resource Management System (PPRM).

Different levels of integration are being built into the system.

### *Maintenance Management System Current Status and Future Plans*

The MMS project began in 2002 and is scheduled for completion in 2005.

## A Synopsis of Other State Practices

The following information summarizes some of the other State DOT asset management systems. These States have stand-alone databases in one or more of the asset categories of this study.

### *North Carolina Department of Transportation*

**Maintenance Management System Description**

The North Carolina Department of Transportation (NCDOT) maintenance management system was developed with the following goals and capabilities in mind:

- Plan, schedule, execute, and manage individual maintenance programs.
- Describe the condition of assets based on extrapolations from random sampling.
- Develop an annual plan both ideal and constrained.
- Create an inventory of assets.
- Facilitate accounting processes.
- Schedule daily maintenance work.

Initially the maintenance management system was released as a pilot program in two divisions for 6 weeks. Field personnel were involved in the initial development of the North Carolina system providing comment and suggestions.

**Maintenance Management System Data Collection**

Visual Maintenance Management System software was acquired from a contractor. The system is a PC-based, three-tiered system with workstation access, an application server, and a mainframe Oracle server. Plans exist to integrate; pilot programs are being deployed in selected divisions.

A visual inspection is used to determine the condition of assets on the sample sections of roadways. All assets in the section, including signs, lighting, supports and structures for signs, guardrails, markings, and detectors receive pass or fail ratings, and the extent of failure is measured.

A condition assessment is performed randomly every 2 years on sample sections of North Carolina highways and freeways. An asset inventory on 126,012 km (78,300 mi) of NCDOT highways has not started.

**Maintenance Management System Current Status and Future Plans**

The vision is to tie together the pavement maintenance, bridge management, and maintenance management systems and eventually add traffic signal management to allow a comprehensive assessment of needs down to the project level.

Training is being offered for a pilot implementation in 2 of 14 divisions.

The GIS is nearing the final stages of development. GIS data will be used to develop a graphical representation of the road network using ArcView® to display maintenance history. Information on each sample section of roadway is included so that engineers can call up sections of roadway and view condition ratings and maintenance needs.

No asset inventory has been initiated, caused in part by budget limitations and competing priorities. The software has the capability for an asset inventory, and it is intended to be used for such in the future.

### *Oregon Department of Transportation*

#### Traffic Signal Information System Description

The goal of the Oregon Department of Transportation (ODOT) in developing the Traffic Signal Information System (TSIS) was primarily for improved maintenance and inventory tracking. One of the stated uses of the tracking capability is to provide support for defense of liability actions brought against the State, potentially producing large savings in legal fees. ODOT anticipates additional benefits to include more effective planning, scheduling, executing, and managing individual maintenance programs. Other cost saving and efficiency producing rationales for developing the TSIS are to allow the State to create an inventory of assets, determine maintenance budgets, facilitate accounting processes, and enhance the expected service life of the asset categories included.

#### Traffic Signal Information System Data Collection

TSIA is a PC-based system running on an SQL database built with Visual Basic and Crystal Reports. The following data will be included in the database:

- Highway location and name.
- Street name.
- Direction of traffic flow.
- Intersecting street name.
- Nearest city.
- Name of county.
- Name of district.
- Region number.
- Name of company supplying power.
- Meter number for location.
- Mile point.
- Date of activation.
- Recent date of repair.
- Months of inspection and maintenance.
- Comments.
- Signal priority.

TSIS is 65 percent to 75 percent populated with accurate data. Data for TSIS are collected and available for reference statewide to ODOT personnel who request access.

### Traffic Signal Information System Current Status and Future Plans

TSIS is fully integrated throughout the ODOT intranet. The current version of TSIS was put into service the first quarter of 2002, but earlier versions of TSIS have been in use since 1990. ODOT has fully populated the data and completed integration throughout the State.

Only individuals in the traffic signal services unit can access TSIS.

### Sign Management System (R2Sign Database) System Description

In 1994, ODOT's Region 2 initiated a grassroots effort to develop a database to track signs in Oregon. In doing so, the region developed the Sign Management System (R2Sign), a PC-based Microsoft Access database system. The primary use of the R2Sign database is for maintenance and inventory tracking, but an additional benefit of tracking is to provide support for defense of liability actions brought against the State. Its main purposes, however, are to provide planning, scheduling, executing, and management for individual maintenance programs and its primary users are the district ODOT sign crews. The database is also used to determine maintenance budget and expected service life.

### R2Sign Data Collection

The database includes the following types of information:

- Location.
- Highway identification.
- Mile point.
- Direction.
- Size of sign.
- Type of sign.
- Sign catalog number.
- Replacement dates and scheduled maintenance dates.
- Installation dates.

Data population varies within regions and districts. While some districts are using R2Sign fully, others do not use it.

Currently, R2Sign is not integrated across the ODOT. This system is not on network-connected computers.

### R2Sign Current Status and Future Plans

R2Sign is being groomed for statewide use. ODOT envisions an integrated network, where all regions are fully using this system. The ODOT technology branch also plans to combine these stand-alone systems into one statewide system.

### *Wisconsin Department of Transportation*

#### Sign Inventory Management System Description

The goals of the Wisconsin Department of Transportation's (WisDOT) Sign Inventory Management System (SIMS) included the ability to allow better planning for the replacement of signs using a system that records the life span of signs. Another goal was for SIMS to ensure that signs are neither prematurely replaced nor remain in the field in poor condition. For cost efficiency, SIMS is expected to provide a useful tool for contractor signing projects; it will permit WisDOT to provide an accurate listing of signs that need to be replaced, enabling the contractor to provide a realistic bid. The system will also facilitate the development of program funding needs annually.

Primary users of SIMS are district sign shops and central office management functions. At this point, districts are required to implement the sign management system; training is provided; and user groups are held to introduce new features of the software as they are implemented.

#### Sign Inventory Management System Data Collection

The following types of information are included in the database:

- Location, county, route, milepost.
- Position on the roadway.
- Sign direction.
- Post type and length.
- Sign code.
- Size.
- Base material.
- Face material.
- Age of sign, manufacturer's date, and installation date.
- Sign description (important for special signs).
- Installation project identification, fleet number, vehicle number.
- Condition (good, fair, or poor).

The database is being populated, and approximately 300,000 signs (70 percent) have been inventoried.

#### Sign Inventory Management System Current Status and Future Plans

The database is in full production; districts are inputting signs as they are installed, repaired, or replaced. The conversion to an Oracle platform will ease integration among all districts and assist in financial planning and projection of statewide 6-year sign replacement costs.

#### Traffic Signal System Inventory System Description

The Traffic Signal System Inventory (TSSI) system has the following purposes:

- To serve three groups of electrical staff for knockdowns and service reports (director's software links different view packages).
- To query information.
- To provide management tracking infrastructure.

TSSI is a PC-based system run on CartêGraph SIGNALview™ software. User groups, including electrical service personnel, engineers, and senior management, are developing data fields and forms. Following development of the data model, operations managers will be presented with findings and level of effort necessary to perform data collection.

**Traffic Signal System Inventory System Data Collection**

A list of data fields that will include a basic description of systems and collect a count of the number and types of systems present on Wisconsin roads (such as controller cabinets and detection systems) is under development.

Through the CartêGraph software, a WORKdirector™ suite will integrate the different View software products (SIGNview, SIGNALview, and MARKINGview™).

**Traffic Signal System Inventory System Current Status and Future Development**

The TSSI initiative began in the spring of 2003, with user groups working to define data fields for signal inventory at that time. At the time of this writing, the data model was projected to be completely developed by the end of 2004. Pending IT issues, actual data collection and inventory are expected to take 2 years or more.

The database will eventually be integrated statewide. One district has begun to gather data on markings. An existing yard inventory will be integrated with the field inventory.

**Marking Management System Description**

The Marking Management System (MMS) was designed to develop quantity needs for contract plans and facilitate annual budget estimates for users, including engineers, financial analysts, and senior management.

**Marking Management System Data Categories**

Data parameters are being defined and probably will include color, type, product make, reflectivity, spotting distance, and roadway surface type.

**Marking Management System Current Status and Future Plans**

The initiative started in spring 2003 and user groups are working to develop data fields and form. The data model was completed in spring 2003, when data collection began. A single pilot program has been initiated in District 6, which has begun to gather data on markings. The marking database is planned to be integrated with various existing databases such as material, pavement, and bridge. The timeframe for integration is unknown, but the completion for data population is targeted for 2005. The database will be integrated statewide.

# CHAPTER 3. CONCLUSIONS

The majority of states, 42 of the 50 surveyed in 2000, indicated they use an asset management system to track their roadway safety hardware; however, for most of those states, the systems entail manual data collection and unintegrated databases. Although the readily available information about roadside assets and the coherent processes for sharing information that are characteristic of an integrated asset management system result in significantly increased effectiveness of State maintenance expenditures, most State DOTs contacted for this report cite fiscal constraints as the primary reason for their inability to upgrade current systems

The implementation of both stand alone and integrated asset management systems often results in an extension of the service life of equipment and increased available funding for maintenance and repairs to State-maintained roadside assets. This type of preventive maintenance tends to not only reduce lifecycle costs, but also improve travel conditions, equipment reliability, and public safety. Indeed, assets such as warning and regulatory signs, edge lining, signals, and roadway lighting have virtually no other purpose than fostering and enhancing highway safety.

In addition to a more efficient use of maintenance funds and improved information management, a number of benefits accrue to States that implement an asset management system:

- A well-maintained collection of safety hardware equipment.
- Improved ability to make pragmatic and cost-effective resource allocation decisions based on complete and accurate information.
- Reduced acquisition, upgrade, and replacement costs for assets.
- Improved management and oversight capabilities.
- Decreased State legal liability that could result from inadequate or faulty safety hardware.

Until fairly recently, a widespread institutional bias has existed among legislators and State DOTs that tends to favor funding new construction and capacity expansion over operations, maintenance, and management of existing facilities. The advent over the past decade or so of the application of asset management principles, particularly with respect to major asset categories such as pavements and bridges, has resulted in a growing trend toward establishing effective preventive maintenance and replacement systems. These systems, in turn, have contributed to a growing culture of extending the useful life of existing safety hardware, thereby decreasing replacement costs.

Asset management may entail a life-cycle cost analysis (that is, taking into account total costs over each asset's operating life) during planning and procurement. This analysis enables the selection of options with the lowest overall long-term costs based on a rational assessment of fact-based scenarios.

At the time of this publication, a number of States were proceeding with initial development of safety hardware asset management systems, and some were working to integrate their current systems with other asset management systems and data sets. A growing number of states are investing considerable effort and resources in more comprehensive and sophisticated approaches to hardware asset management systems, an endeavor that clearly lends itself to cooperative multistate development efforts through such mechanisms as AASHTO and the regional State DOT associations.

# Appendix A. FHWA Letter to Division Offices

**October 2002**

On behalf of the FHWA Office of Safety R&D, Office of Safety and Office of Asset Management, we have initiated through a contractor the next phase of the Hardware and Safety Management System work with AASHTO. The project is entitled: "The Development of Guidance Material for Hardware Asset Management."

The project involves documentation of what the leading or best practices are for hardware and safety management systems. Approximately 5 to 10 states are being contacted for case studies that will be documented in a primer. A catalog of the tools (software, hardware and others) that state DOTs and other agencies are using will also be developed. The primer and catalog are expected to be available in 2004.

Attached to this e-mail are the summary results from a 2000 Roadway Management Survey of states performed by AASHTO. This survey provides information regarding states' roadway asset management inventory.

If you would like to update your state's information, or for the states that did not respond, submit information regarding the survey, please feel free to forward this to me. Any information that you provide may also be used in the contract identified above in the selection of the five–ten states for case study. (Note: When States responded to the initial AASHTO survey, they were aware of the potential for follow up survey, if they were conducting innovative practices.)

Also, if you are familiar with any private systems that should be considered by the contractor for best practice, please forward this information as well.

The contract also involves the development of a marketing plan for distribution and transfer of the technology for the project. If you have any early input in this regard, it is appreciated. Please also indicate if you would like to be listed on the Technology Facilitation Action Plan for this project as a continuing field contact.

I will be serving as the COTR for this contract and appreciate your time regarding this matter. If you have any questions, comments or suggestions, please feel free to contact me at your convenience.

Regards, John

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# Appendix B. Questionnaire to State DOTs

Following is a list of questions sent to State DOTs in 2000.

1. Contact Office/Person
2. System Description
3. System Background
4. Current System Status
5. Data Categories
6. Status of Data Population
7. Status of Integration
8. System Requirements
    - Software
    - Hardware
9. Cost
10. Quality Assurance
11. Primary Users
12. Training
13. State Contractors
14. System Marketing Plan
15. Future Development
16. Other Information
17. References

# Appendix C. Summary of AASHTO Survey Results

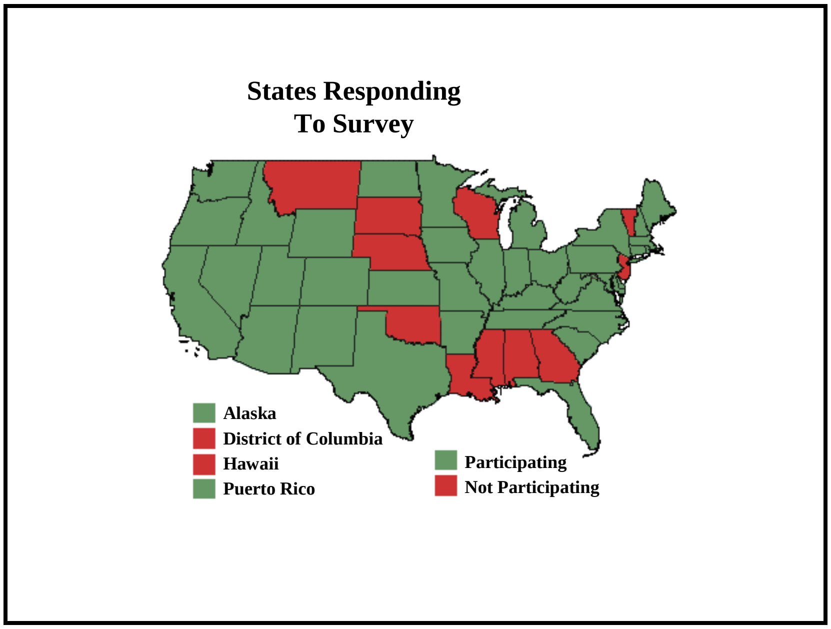


**Figure 10. Map. Geographic map showing States that responded to AASHTO survey.**

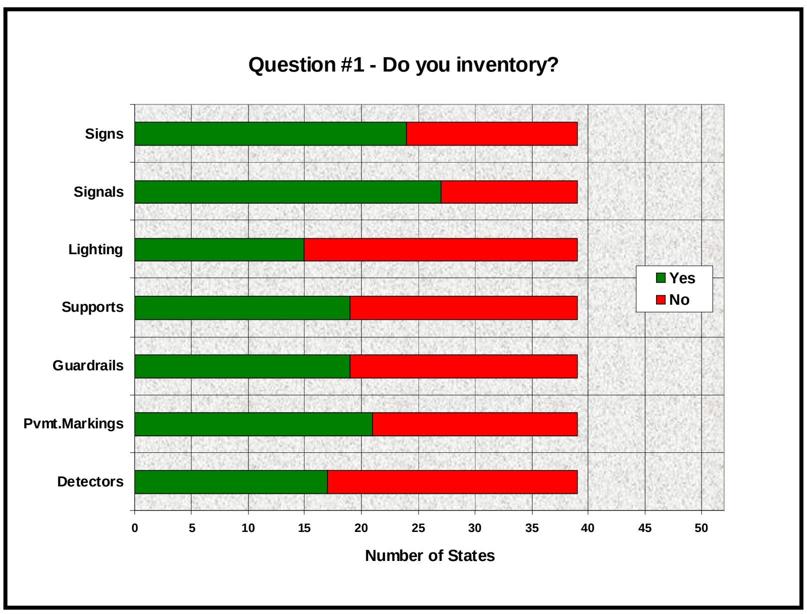


**Figure 11. Graph. AASHTO survey results to question # 1: Do you inventory?**

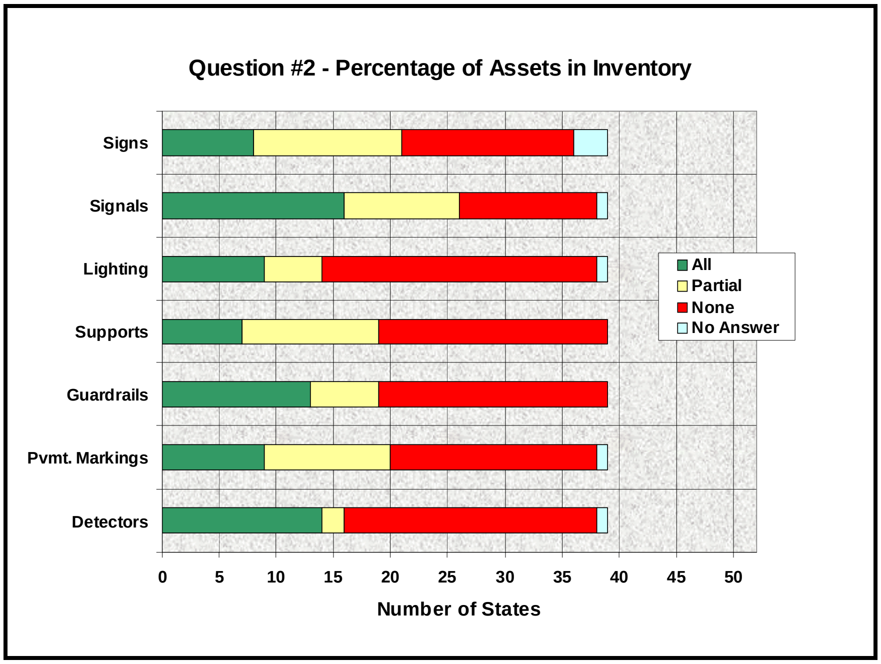


**Figure 12. Graph. AASHTO survey results to question #2: Percentage of assets in inventory.**

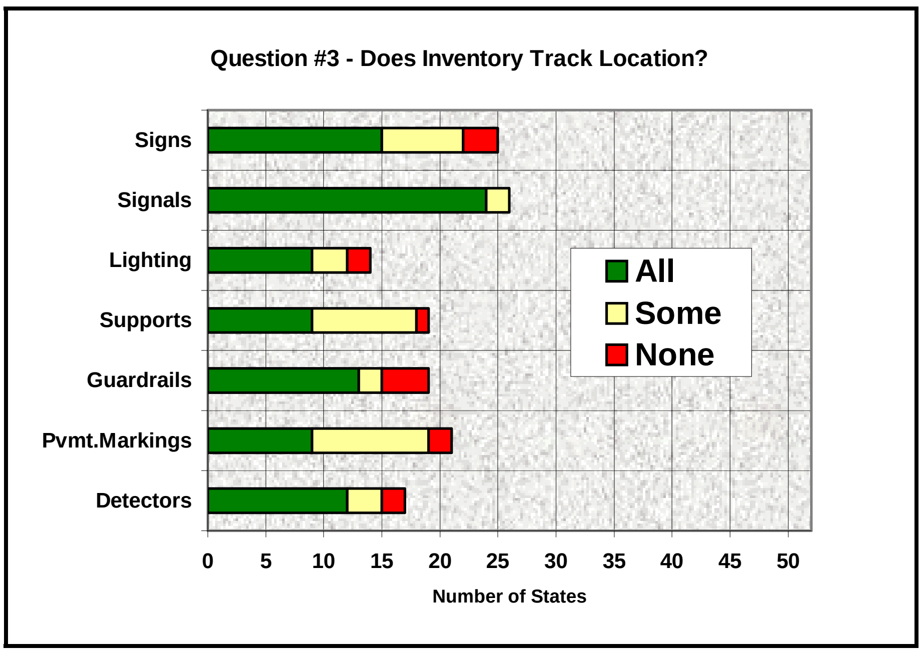


**Figure 13. Graph. AASHTO survey results to question #3: Does inventory track location?**

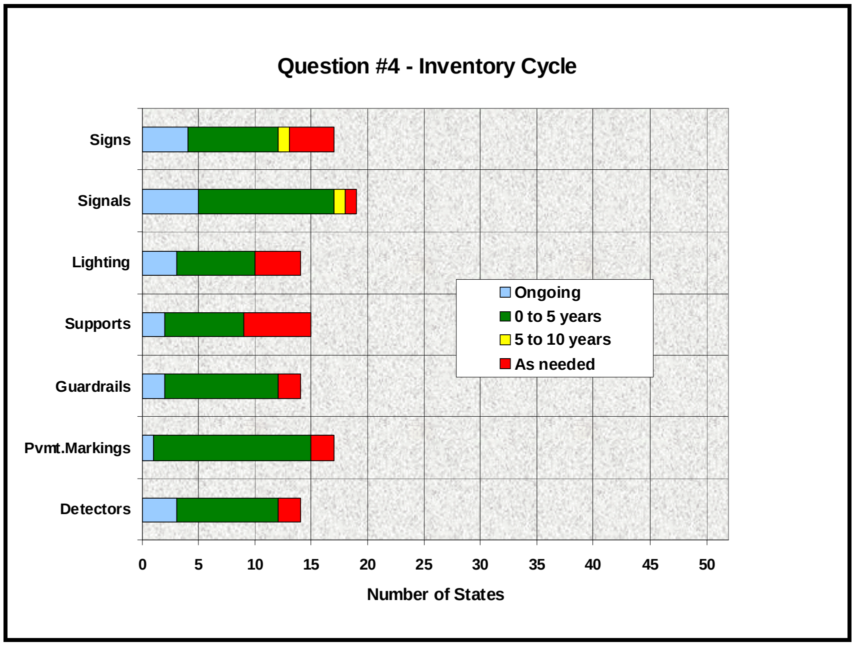


**Figure 14. Graph. AASHTO survey results to question #4: Inventory cycle.**

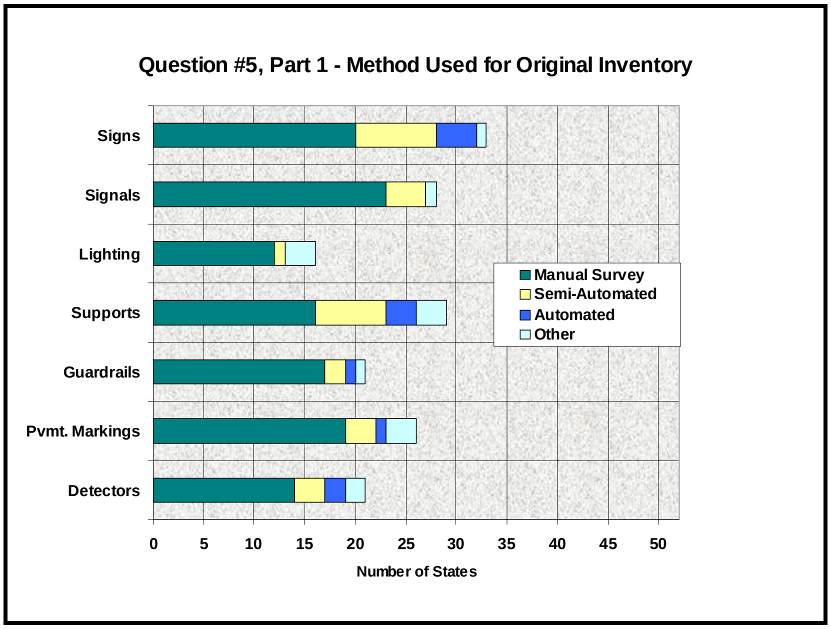


**Figure 15. Graph. AASHTO survey results to question #5 (part 1): Method used for original inventory.**

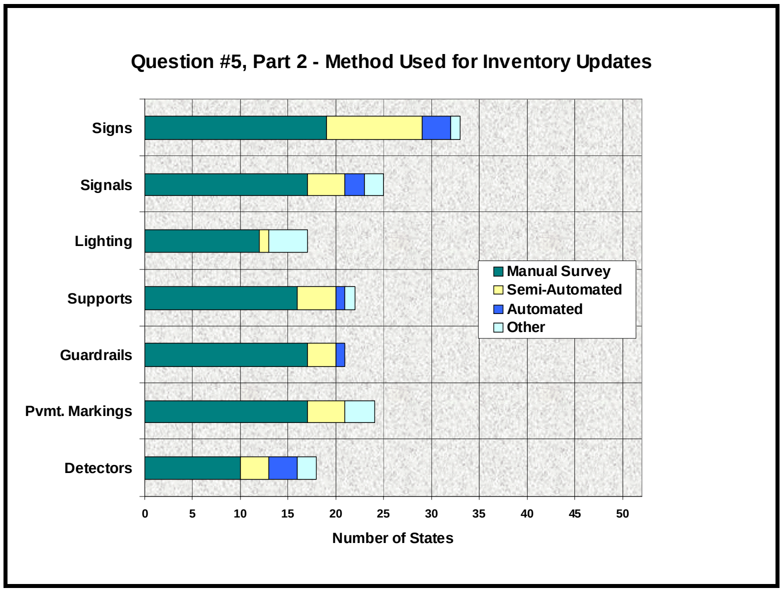


**Figure 16. Graph. AASHTO survey results to question #5 (part 2): Method used for inventory updates.**

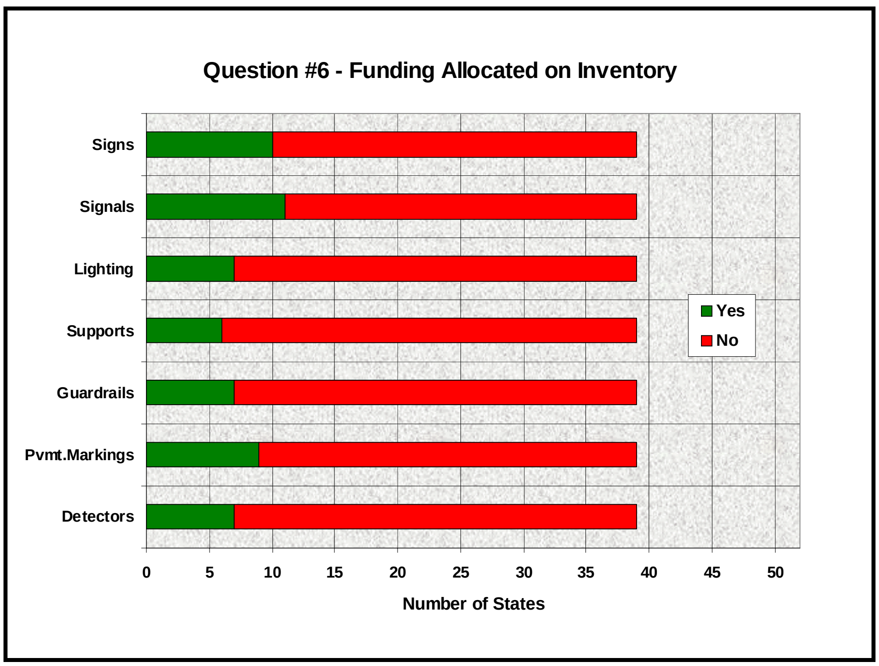


**Figure 17. Graph. AASHTO survey results to question #6: Funding allocated on inventory.**

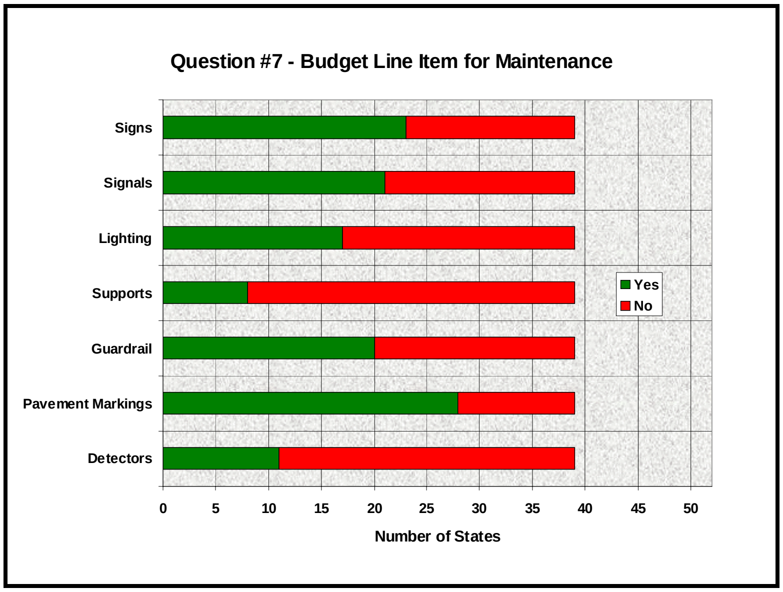


**Figure 18. Graph. AASHTO survey results to question #7: Budget line item for maintenance.**

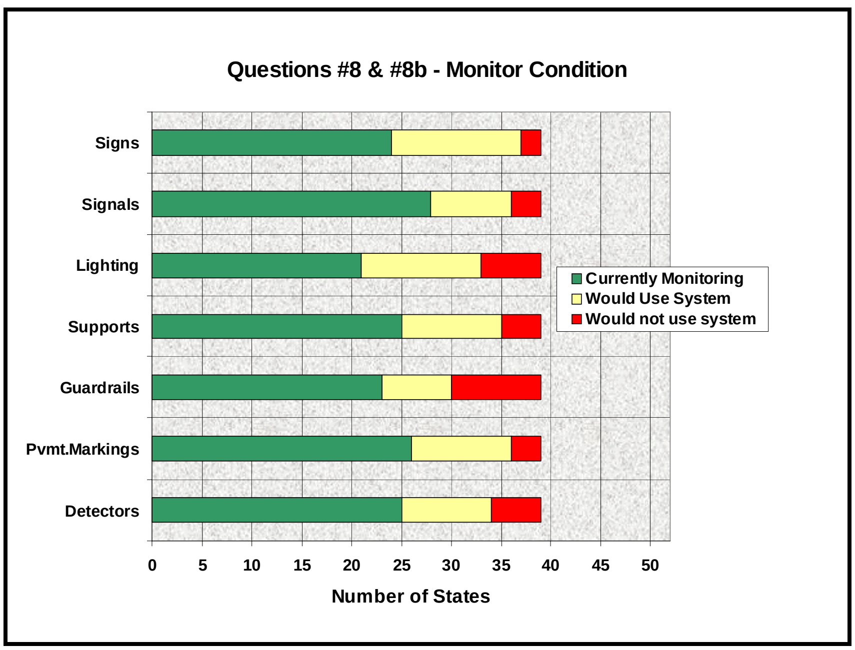


**Figure 19. Graph. AASHTO survey results to questions #8 and 8b: Monitor condition.**

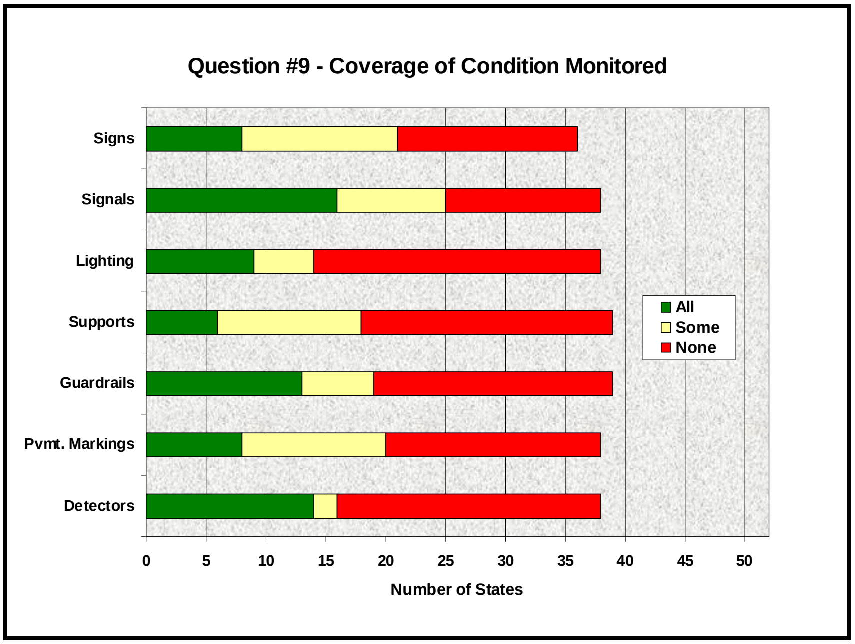


**Figure 20. Graph. AASHTO survey results to question #9: Coverage of condition monitored.**

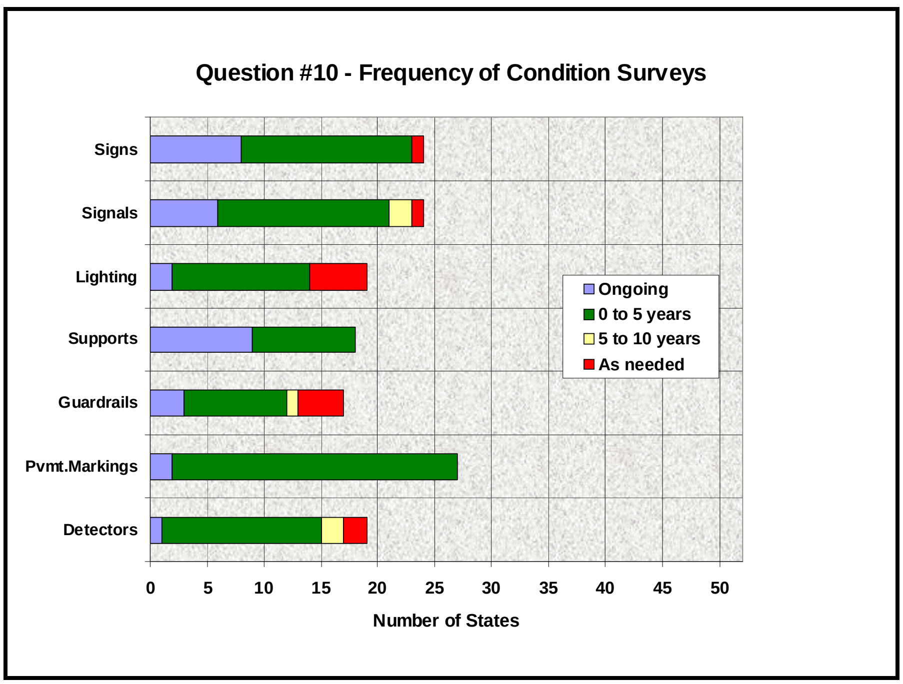


**Figure 21. Graph. AASHTO survey results to question #10: Frequency of condition surveys.**

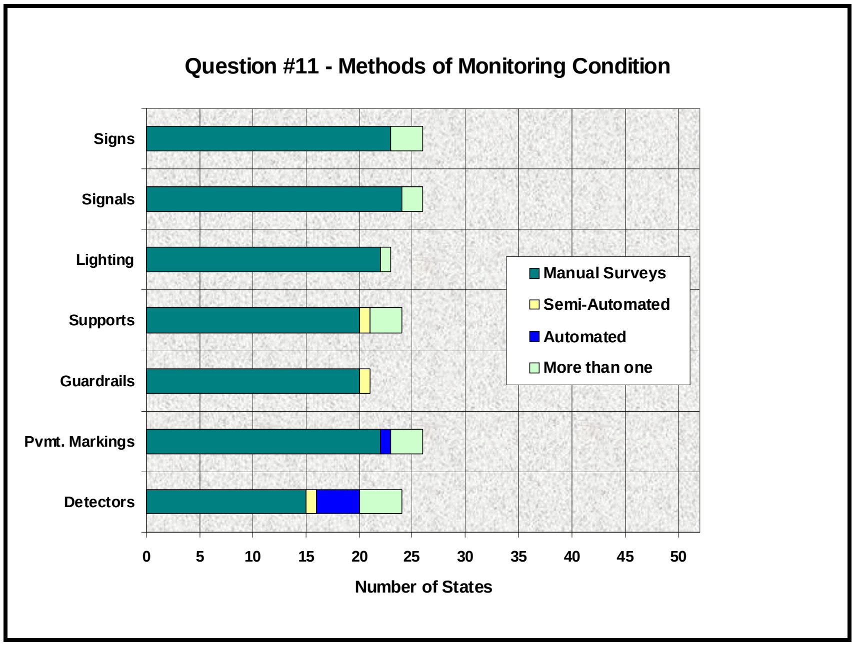


**Figure 22. Graph. AASHTO survey results to question #11: Methods of monitoring condition.**

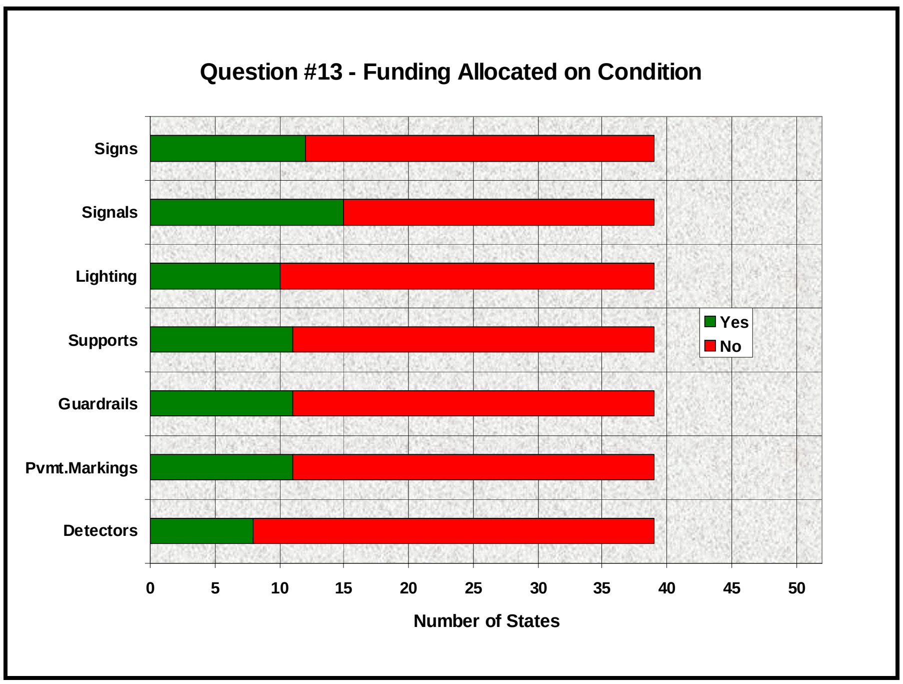


**Figure 23. Graph. AASHTO Survey Results to question #13: Funding allocated on condition.**

# Appendix D. List of State DOT Contacts

The following individual State contact offices were provided, in part, by AASHTO.

**Table 15. State contact offices.**

| State | DOT Address and Point of Contact | Contact Phone |
|---|---|---|
| **Alaska** | | |
| | State Transportation Engineer<br>Alaska Department of Transportation<br>3132 Channel Dr.<br>Juneau, AK 99801 | (907) 465-6963 |
| **Arizona** | | |
| | State Traffic Engineer<br>Arizona Department of Transportation<br>1655 W. Jackson St.<br>Phoenix, AZ 85007-3217 | (602) 712-8888 |
| | Assistant State Engineer | (602) 712-6622 |
| | State Engineer | (602) 712-7391 |
| **Arkansas** | | |
| | Chief Engineer<br>Arkansas State Highway and Transportation Department<br>10324 Interstate 30<br>Little Rock, AK 72209 | (501) 569-2214 |
| | Staff Traffic Engineer | (501) 569-2661 |
| | Staff Traffic Engineer | (501) 569-2232 |
| | Asst. Roadway Design Engineer | (501) 569-2336 |
| | Staff Planning Engineer | (501) 569-2111 |
| **California** | | |
| | Electrical Support Staff, Superintendent, or Traffic Engineer<br>1120 N. Street<br>Sacramento, CA 95814 | 916-654-2924<br>916-684-1822 |
| **Colorado** | | |
| | Traffic Engineer<br>4201 E. Arkansas Avenue<br>Denver, CO 80222 | (303) 512-5100 |
| | Standards Engineer | (303) 757-9083 |
| **Connecticut** | | |
| | Manager of Traffic Engineering<br>2800 Berlin Turnpike<br>Newington, CT 06131-7546 | (860) 594-2710 |
| | Trans. Principal Engineer | (860) 594-2608 |
| | Trans. Engineer 2 | (860) 594-3177 |
| | Trans. Maint. Planner III | (860) 594-2616 |

**Table 15. State contact offices—Continued**

| State | DOT Address and Point of Contact | Contact Phone |
|---|---|---|
| **Delaware** | | |
| | Director, Div. Of Hwy. Ops<br>Headquarters Administration Center<br>800 Bay Road<br>P.O. Box 778<br>Dover, DE 19903 | (302) 760-2201 |
| | Chief Traffic Engineer | (302) 739-4362 |
| | Comtech Engineer | (302) 760-2188 |
| **Florida** | | |
| | State Highway Maintenance Engineer<br>Florida Department of Transportation<br>605 Suwannee Street<br>Tallahassee, FL 32399 | (850) 414-4704 |
| | Traffic Services Engineer | (850) 488-4562 |
| | Transportation Statistics Office | (850) 488-4562 |
| **Georgia** | | |
| | Maintenance Activities Engineer<br>Georgia Department of Transportation<br>25 Kennedy Drive<br>Forest Park, GA 30297 | (404) 363-7625 |
| **Idaho** | | |
| | Acting Traffic Engineer<br>3311 W. State Street<br>P.O. Box 7129<br>Boise, ID 83707-1129 | (208) 334-8557 |
| | Trans. Staff Eng. Asst. | (208) 334-8565 |
| | Trans. Staff Eng. Asst. | (208) 334-8571 |
| **Illinois** | | |
| | Traffic Operations Engineer<br>Illinois Department of Transportation<br>2300 S. Dirksen Pkwy.<br>Springfield, IL 62764 | (217) 782-2076 |
| | Field Operations Engineer | (217) 782-2984 |
| **Indiana** | | |
| | Highway Support Manager<br>100 N. Senate Ave.<br>Indianapolis, IN 46204 | (317) 232-5508 |
| | Traffic Field Engineer | (317) 232-5549 |
| | Maintenance Field Engineer | (317) 232-5551 |

## Table 15. State contact offices—Continued

| State | DOT Address and Point of Contact | Contact Phone |
|---|---|---|
| **Iowa** | | |
| | Highway Division Director<br>Iowa Department of Transportation<br>800 Lincoln Way<br>Ames, IA 50010 | (515) 239-1124 |
| | State Traffic Engineer | (515) 239-1513 |
| | Assistant Office Director | (515) 239-1396 |
| | Bridge Maintenance Engineer | (515) 239-1165 |
| | Asst. Office Director | (515) 239-1396 |
| | Telemetrics Coordinator | (515) 239-1172 |
| **Kansas** | | |
| | Director/Division of Operations<br>Kansas Department of Transportation<br>Dwight D. Eisenhower State Office Building<br>700 S.W. Harrison Street<br>Topeka, KS 66603-3754 | (785) 296-2235 |
| | Senior Traffic Signing Engineer | (785) 296-3618 |
| | State Traffic Engineer | (785) 296-3618 |
| | Overhead Sign Structure Engineer | (785) 296-5559 |
| | Asst. Bureau Chief/Const. & Maint. | (785) 296-3576 |
| **Kentucky** | | |
| | Deputy State Highway Engineer<br>James K. Polk Building<br>505 Deaderick Street<br>Suite 700<br>Nashville, TN 37243-0349 | (502) 564-3730 |
| | Director | (502) 564-3020 |
| | Tr Eng Br Mgr | (502) 564-4556 |
| | Transportation Engineer Specialist | (502) 564-4556 |
| **Maine** | | |
| | State Traffic Engineer<br>Maine Department of Transportation<br>3 Child Street, State House Station #16<br>Augusta, ME 04333-0016 | (207) 287-3775 |
| | Engineering Technician | (207) 287-3775 |
| | Civil Engineer | (207) 287-3775 |
| | Striping Manager | (207) 287-3745 |

**Table 15. State contact offices—Continued**

| State | DOT Address and Point of Contact | Contact Phone |
|---|---|---|
| **Maryland** | | |
| | Assistant Division Chief<br>Highway Information Services Division<br>Office of Planning and Preliminary Engineering<br>707 N. Calvert St.<br>Baltimore, MD 21202 | (410) 545-5537 |
| | Transportation Engineer | (410) 582-5569 |
| | Statewide Pavement Marking Coordinator | (410) 582-5520 |
| | Team Leader, Structures Team | (410) 787-5853 |
| | Asst. Division Chief<br>Traffic Engineering Design Division | (410) 787-4022 |
| **Massachusetts** | | |
| | Assistant Chief Engineer<br>The Executive Office of Transportation<br>10 Park Plaza, Suite 3170<br>Boston, MA 02116 | (617) 973-7516 |
| | Manager, Signs and Pavement Marking | (617) 973-7375 |
| | Civil Engineer IV | (617) 973-7373 |
| | Manager, Electrical System | (617) 973-7363 |
| | Maintenance Engineer | (617) 973-7799 |
| | Director ITS Programs | (617) 973-7315 |
| **Michigan** | | |
| | Supervising Engineer, Traffic Signs<br>and Delineation Unit<br>State Transportation Building<br>425 W. Ottawa St.<br>P.O. Box 30050<br>Lansing, MI 48909 | (517) 335-2625 |
| | Supervising Engineer, Traffic Signals Unit | (517) 373-2324 |
| | EML 14 | (517) 373-0733 |
| | Staff Specialist-Roadside Safety | (517) 335-2991 |
| **Minnesota** | | |
| | Maintenance Operations<br>Office of Traffic Engineering and Intelligence<br>Transportation Systems<br>Mailstop 725<br>2nd floor North<br>395 John Ireland Blvd<br>St. Paul, MN 55155-1899 | (651) 282-2281 |
| | Electronics Traffic Maintenance Superintendent | (612) 725-2305 |
| | State Lighting Engineer | (651) 284-3470 |
| | State Signing Engineer | (651) 284-3440 |
| | Traffic Electrical Systems Engineer | (651) 284-3434<br>(651) 205-4526 |

**Table 15. State contact offices—Continued**

| State | DOT Address and Point of Contact | Contact Phone |
|---|---|---|
| **Missouri** | | |
| | Technical Support Engineer<br>MoDOT<br>Central Office<br>105 W. Capitol Avenue<br>Jefferson City, MO 65102 | (573) 526-0121 |
| | Design Standards Engineer | (573) 526-2903 |
| **Nevada** | | |
| | Chief Safety/Traffic Engineer<br>Nevada Department of Transportation<br>1263 South Stewart Street<br>Carson City, NV 89712 | (775) 888-7490 |
| | Asst. Bridge Engineer | (775) 888-7545 |
| **New Hampshire** | | |
| | Traffic Maint. Supervisor<br>New Hampshire Department of Transportation<br>John O. Morton Building<br>7 Hazen Drive<br>Concord, NH 03302-0483 | (603) 271-2291 |
| | Traffic Engineer | (603) 271-2291 |
| | P.M. Operations Supervisor | (603) 271-2291 |
| **New Mexico** | | |
| | Operations and Maintenance, or<br>Bureau of Maintenance and Traffic Services<br>P.O. Box 1149<br>Santa Fe, NM 87504 | (505) 827-5525 |
| **New York** | | |
| | Director Design Quality Assurance Bureau<br>1220 Washington Ave., Bldg. 5 - Rm. 410<br>Albany, NY 12232-0751 | (518) 457-6467<br>Fax: (518) 457-6477 |
| | Assistant Commissioner for Eng | (518) 457-4430 |

### Table 15. State contact offices—Continued

| State | DOT Address and Point of Contact | Contact Phone |
|---|---|---|
| **North Carolina** | | |
| | Traffic Engineering Staff Engineer<br>North Carolina Department of Transportation<br>1500 Mail Service Center<br>Raleigh, NC 27699-1500 | (919) 715-7736 |
| | Signing Engineer | (919) 250-2145 |
| | Signals Management Engineer | (919) 733-5666 |
| | Transportation Electrical Engineer. | (919) 250-4128 |
| | Road Maintenance Operations Engineer | (919) 733-3725 |
| | Traffic Control Engineer | (919) 250-4151 |
| | MMS Project Office<br>Global Software Building<br>3200 Atlantic Avenue, Suite 205<br>Raleigh, NC 27604 | (919) 573-7252 |
| **North Dakota** | | |
| | Traffic Data Manager<br>North Dakota Department of Transportation<br>608 East Boulevard Avenue<br>Bismarck, ND 58505-0700 | (701) 328-4401 |
| | Deputy Director for Engineering | (701) 328-2584 |
| | Roadway Data Manager | (701) 328-3479 |
| | Traffic Operations Engineer | (701) 328-4398 |
| | Structure Management | (701) 328-4448 |
| | Asst. Maintenance Engineer | (701) 328-2545 |
| **Ohio** | | |
| | Assistant Director/Chief Engineer<br>Ohio Department of Transportation<br>1980 W. Broad St.<br>Columbus, OH 43223 | (614) 466-2448 |
| | Administrator, Traffic | (614) 644-8137 |
| | Maintenance Manager | (614) 644-7155 |
| | Deputy Director<br>Office of Roadway Engineering Services | (614) 644-1203 |
| | | |

**Table 15. State contact offices—Continued**

| State | DOT Address and Point of Contact | Contact Phone |
| --- | --- | --- |
| **Oregon** | | |
| | Technical Services Manager<br>Oregon DOT<br>355 Capitol St., N.E.<br>Salem, OR 97301 | (503) 386-3302 |
| | Sign Engineer | (503) 986-3603 |
| | Transportation Operations Engineer | (503) 986-3489 |
| | Traffic Design Engineer | (503) 986-3583 |
| | Standards Engineer | (503) 986-3779 |
| | Sr. Traffic Investigator | (503) 986-3573 |
| | Traffic Operations | (503) 986-4062 |
| | Field Operations | (503) 986-4485 |
| **Pennsylvania** | | |
| | Manager, Sign Standards & Manufacturing<br>PENNDOT Central Office<br>Keystone Building<br>400 North Street<br>Harrisburg, PA 17120 | (717) 783-6261 |
| | Manager, Congestion Management and Signalization Section | (717) 787-9787 |
| | Civil Engineer Manager | (717) 78-6263 |
| | Chief Highway Lighting | (717) 772-3077 |
| | Manager, Traffic Engineering & Operations Division | (717) 787-3620 |
| | Manager, Highway Safety Engineering | (717) 705-1706 |
| | Manager, Markings and Delineation | (717) 772-5462 |
| | ATMS/ATIS Section Manager | (717) 705-1447 |
| | Trans. Planning Specialist | (717) 787-1840 |
| **Puerto Rico** | | |
| | Deputy Exec. Director Infrastructure | (787) 729-1554 |
| | Director-Design Area | (787) 729-1575 |
| | Dep. Exec. Director for Traffic & Ops | (787) 729-1538 |
| **Rhode Island** | | |
| | Chief Civil Engineer<br>Rhode Island Department of Transportation<br>Two Capitol Hill<br>Providence, RI 02903 | (401) 222-2694, ext. 4202 |
| | Maintenance Engineer | (401) 222-2378 |
| | Principal Civil Engineer | (401) 222-2694, ext. 4203 |

**Table 15. State contact offices—Continued**

| State | DOT Address and Point of Contact | Contact Phone |
|---|---|---|
| **South Carolina** | | |
| | Traffic Programs Engineer<br>South Carolina Department of Transportation<br>955 Park Street<br>P.O. Box 191<br>Columbia, SC 29202-0191 | (803) 737-1994 |
| | Traffic Services Coordinator | (803) 737-1500 |
| | Advanced Systems Coordinator | (803) 737-1646 |
| | Signing and Marking Plan Preparation Engineer | (803) 737-2086 |
| **Tennessee** | | |
| | Director, Maintenance Division<br>505 Deaderick Street, Suite 400<br>James Polk Bldg.<br>Nashville, TN 37243 | (615) 741-2027 |
| | State Traffic Engineer | (615) 741-2466 |
| | Project Manager<br>505 Deaderick Street, Suite 1200<br>James Polk Bldg.<br>Nashville, TN 37243 | (615) 253-6421 |
| | Transportation Manager<br>505 Deaderick Street, Suite 1000<br>James Polk Bldg.<br>Nashville, TN 37243 | (615) 741-2208 |
| **Texas** | | |
| | Director of Traffic Operations Division | (512) 416-3200 |
| | Policy and Standards Engineer | (512) 416-3120 |
| | Signal & Radio Operations Branch Manager | (512) 416-3149 |
| | Senior Lighting Design Engineer | (512) 416-3121 |
| | Geometric Design Engineer | (512) 416-2653 |
| **Utah** | | |
| | Traffic Studies Engineer | (801) 964-4521 |
| | Engineer for Maintenance | (801) 965-4120 |
| | Director, Traffic Operations Center | (801) 887-3707 |
| **Virginia** | | |
| | Asset Management Division<br>1401 East Broad Street<br>Richmond, VA 23219 | (804) 371-1265<br>Fax: (804) 371-2037 |
| | Assistant For Systems Development<br>Asset Management Division | (804) 371-2978<br>Fax: (804) 371-2037 |

**Table 15. State contact offices—Continued**

| State | DOT Address and Point of Contact | Contact Phone |
|---|---|---|
| **Washington** | | |
| | Signing Engineer<br>Washington State Department of Transportation<br>310 Maple Park Avenue SE<br>PO Box 47300<br>Olympia WA 98504-7300 | (360) 705-7988 |
| | Traffic Signal Engineer | (360) 705-7284 |
| | Design Policy with Standards Engineer | (360) 705-7269 |
| **West Virginia** | | |
| | Special Projects and Programs Engineer<br>Building 5<br>1900 Kanawha Blvd. E.<br>Charleston WV 25305 | (304) 558-3063 |
| | Systems Management & Traffic Services Eng | (304) 558-3063 |
| **Wisconsin** | | |
| | Wisconsin DOT<br>4802 Sheboygan Ave.<br>Madison, WI 53707-7910 | (608) 266-1260 |
| **Wyoming** | | |
| | State Traffic Engineer<br>WYDOT Headquarters<br>5300 Bishop Blvd<br>Cheyenne, WY 82009-3340 | (307) 777-4492 |

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