



Roadway and Roadside Visual Image and Attribute Data Collection and Distribution

Requested by
Matt Friedman, Caltrans Division of Traffic Operations

March 24, 2015

The Caltrans Division of Research, Innovation and System Information (DRISI) receives and evaluates numerous research problem statements for funding every year. DRISI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field. The contents of this document reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation, the State of California, or the Federal Highway Administration. This document does not constitute a standard, specification, or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor, or consultant. Any trade names or photos of commercial products appearing in this publication are for clarity only.

Table of Contents

Executive Summary	2
Background.....	2
Summary of Findings.....	2
Gaps in Findings.....	5
Next Steps.....	5
Detailed Findings	6
Survey of Current Practice.....	6
Related Research and Resources.....	15
Contacts	24

Executive Summary

Background

Caltrans' Division of Traffic Operations is seeking to modernize its photolog program for collecting, analyzing and distributing roadway and roadside visual images and feature attributes. Although existing equipment is capable of accurately representing highway conditions, the equipment is obsolete, often fails, and some elements are not supported by providers. A 2014 survey by Caltrans found a significant number of users of Caltrans photolog data, especially for asset identification and condition analysis; results suggested that the data can help improve safety and stewardship of state resources. The survey also showed that users were highly interested in seeing the system updated to be more user-friendly and to adopt new and emerging technologies.

To help develop an RFP for upgrading this software, Caltrans is interested in learning about the technologies used by other states as well as internationally, both for collecting data and for sharing it with users on a web-based platform.

To assist Caltrans in developing this RFP, CTC & Associates:

- Gathered information about state practices and experiences with the technologies through email and phone surveys.
- Interviewed vendors Fugro and Mandli for clarification about emerging technologies.
- Performed a literature review of emerging trends in roadway and roadside visual image and attribute collection and distribution software.

Summary of Findings

Survey of Current Practice

CTC queried eight state departments of transportation (DOTs) about the technologies they use to collect, analyze and distribute roadway and roadside visual images and feature attributes. CTC is also attempting to contact European transportation agencies and will update this Preliminary Investigation when results are available.

Six states responded to our questions. Four respondents (Connecticut DOT, Maryland State Highway Administration (SHA), Minnesota DOT and Tennessee DOT) use only photographic imaging. Two (Arizona DOT and Utah DOT) use both photographic imaging and LiDAR. Two respondents (Tennessee DOT and Utah DOT) contract out data collection, while all others perform it themselves. All DOTs conduct data analysis in-house, with only Connecticut DOT also contracting this task out in some cases. Current vendors used by DOTs for equipment and data collection include Geo-3D/Trimble, Fugro and Mandli. Only three respondents planned to upgrade their systems with emerging technologies: Arizona DOT is looking into 360-degree photo imaging and 360-degree higher resolution LiDAR as well as improved data extraction software available through vendors Leica, Fugro and Immersive Media. Connecticut DOT may acquire a Pavemetrics 3D laser pavement scanner, while Utah DOT is still refining its extensive, custom-built data analysis systems.

State	Current Technologies		Distribution	Work	Emerging Technologies
	Data Collection	Data Analysis			
Arizona	Photo imaging and LiDAR Geo-3D/ Trimble	Trident Analyst (by Geo-3D)	Internally: In-house viewer Externally: External hard drive to business partners	All in-house	360-degree photo imaging, 360-degree higher resolution LiDAR, data extraction software Leica, Fugro, Immersive Media
Connecticut	Photo imaging Fugro	DigitalHIWAY	Internally: Intranet (DigitalHIWAY) Externally: Upon request (unspecified tech)	Mostly in-house (some contract data extraction)	Pavemetrics 3D laser scanning
Maryland	Photo imaging Unspecified vendor	Unspecified	Internally: Intranet (unspecified tech) Externally: Unspecified tech	All in-house	None
Minnesota	Photo imaging Unspecified vendor	Unspecified	Internally: Citrix Server Externally: External hard drive	All in-house	None
Tennessee	Photo imaging Mandli	Intergraph web-based application	Internally: Intranet (Intergraph) Externally: Upon request to city governments and contractors (unspecified tech)	Mandli for data collection In-house analysis	None
Utah	Photo imaging and LiDAR Fugro, Mandli	Extensive custom system built by multiple vendors and integrated into all business systems	Web-based application, both internally and to the general public	Fugro, Mandli for data collection In-house analysis	Still refining its custom system for data analysis/extraction and business system integration

Highlights from DOT responses follow:

- Arizona DOT uses a system built by Geo-3D (now a subsidiary of Trimble) to collect photogrammetric and LiDAR data. For data analysis, it uses Trident Analyst, which seems to include extensive tools for feature extraction. All data collection and analysis work is done in-house; asset extraction is labor-intensive. For distribution, Arizona DOT uses an in-house viewer that allows internal users to view more than 10 years of data. Distribution outside the agency is limited to business partners and supplied via external hard drive. Arizona DOT was the first DOT to actively log its highway system with LiDAR. It has begun looking for the next generation of equipment, including technologies offered by Leica, Fugro and Immersive Media. LiDAR is becoming much more capable and cost-effective, and Arizona DOT is interested in both 360-degree photography and 360-degree LiDAR scanners with greater point cloud densities. It is also looking at software that can better extract information from its photolog.
- Connecticut DOT uses two Fugro Roadware ARAN vans outfitted with HDTV cameras, GPS and other sensors for data collection. It uses DigitalHIWAY System for processing and distribution. Most work is done in-house, although some data extraction is contracted. Data are available to DOT users through its intranet and outside the DOT upon request. The agency has looked into LiDAR and photogrammetry, but has no plans for making the necessary financial commitments to acquire these technologies in the near future. It may acquire Pavemetrics 3D pavement scanning lasers.
- Maryland SHA currently uses ultra-high-definition digital images from two calibrated cameras, available internally via its intranet and also externally. All work is performed in-house. The agency has no plans to adopt emerging technologies.
- Minnesota DOT uses photographic imaging. Data are available internally via Citrix Server and externally upon request via external hard drive. All work is done in-house. The interviewee was unaware of plans to adopt emerging technologies.
- Tennessee DOT uses photographic imaging, contracting out to Mandli in the past on a two-year cycle. For data analysis and distribution, the agency uses a web-based application developed by Intergraph. Data are available within the DOT via its intranet or upon request to city governments and contractors. All work is contracted out. Tennessee DOT has no plans to adopt emerging technologies.
- Utah DOT has an extensive photolog program using both LiDAR and high-definition images. Its photolog is extensively integrated into all business systems, including asset management, safety and design analysis. Utah DOT has used Fugro and Mandli for data collection; its data analysis and distribution system was built with the pro bono collaboration of numerous companies. Data are available both internally and externally through the web without a login.

Consultation with Vendors

We contacted representatives at Fugro and Mandli. Both noted that the trend in emerging technologies is toward higher resolution, higher frequency LiDAR as well as improved data analysis and asset extraction. Damion Orsi, product manager at Fugro, said that high-resolution photo imaging is still more cost-effective than LiDAR, the resolutions of which are not required for asset management.

Related Research and Resources

Based on survey results, CTC conducted a literature search of mobile LiDAR, photographic imaging and software for analysis and data extraction. Highlights include:

- NCHRP's Guidelines for the Use of Mobile LiDAR in Transportation Applications, which includes comprehensive chapters on applications, workflow and data management, procurement and implementation. See Chapter 17 for emerging technologies, which include an increase in scanner range, speed, accuracy and portability; systems integration; 3D point cloud reconstruction from 2D images; and Flash LiDAR.
- Washington State DOT's LiDAR for Data Efficiency for a comparative evaluation of various LiDAR vendors in the field.
- Michigan DOT's Monitoring Highway Assets with Remote Technology, which evaluates several technologies, including photographic imaging and LiDAR. It recommends photographic imaging for its cost-effectiveness.
- Use of Traffic Speed LiDAR in Road Asset Management, which develops an algorithm for identifying roadside barriers in data.
- "Road Extraction from LiDAR Data Using Support Vector Machine Classification," which presents a method for extracting features from LiDAR data.

Gaps in Findings

- Several states were not specific about the technologies and vendors they use. Only one state seems to be planning a significant upgrade to the latest emerging technologies. Other states not contacted for this Preliminary Investigation may also be embracing emerging technologies.
- Interview and research results do not clarify how advanced feature extraction processes are for LiDAR data. Automating this process is an emerging technology, but it's not clear how mature it is.
- A limited number of research and pilot studies are available about emerging technologies.
- CTC is still awaiting responses from contacts at European transportation agencies. We were not able to include interview results from those organizations in this report.

Next Steps

Moving forward, Caltrans might consider:

- Following up with Arizona DOT, which is also exploring emerging technologies.
- Following up with Utah DOT to get more details about its extensive custom data analysis system, which is integrated into its business systems.
- Contacting Gene Rowe of TRB and Paul Carlson of the Texas Transportation Institute, recommended by John Caya of Mandli, for more information about the latest developments in mobile LiDAR.
- Contacting vendors for further detailed information about roadside data collection and analysis systems, including costs, benefits and the required resolutions for specific tasks.

Detailed Findings

Survey of Current Practice

To learn about the latest and most effective technologies being used by other transportation agencies, we contacted DOTs by email and telephone with the following questions:

1. What technologies (such as LiDAR or photogrammetry) do you currently use for your photolog program for data collection, analysis and distribution?
2. What data are available to users and how are they distributed?
3. What emerging technologies have you explored and who are the vendors?
4. Have you adopted or moved to adopting an emerging technology?
5. Do you perform in-house data collection, analysis and distribution; contract any of the work; or have some in-house and some contracted work?
6. How do you use, or plan to use, photolog data to meet asset management requirements of MAP-21, such as creating an asset inventory?
7. Are your data available to users outside of your DOT?

We sent these questions to eight departments of transportation (Arizona, Connecticut, Maryland, Minnesota, New Hampshire, Tennessee, Texas and Utah) and received six responses. CTC is also attempting to present these same questions to European transportation agencies; we will forward responses to Caltrans once they are received.

Survey responses are detailed below. In some cases, responses have been edited slightly for clarity, and in others we have combined the results of email correspondence and a phone interview.

Arizona

Contacts: James Meyer, GIS Program Manager, Arizona Department of Transportation, 602-712-8037, jmeyer@azdot.gov.

Robert Bush, Transportation Photolog Specialist, Arizona Department of Transportation, 602-712-7248, ext. 8590, rbush@azdot.gov.

Responses were received by email and conference call.

1. Technologies

For data collection, Arizona DOT currently uses a system built by Geo-3D (now a subsidiary of Trimble): 2 HD cameras collecting at 2448 X 2048 resolution every 10 meters of mainline highway collection. Additionally, it has two SICK laser scanners that operate at 75 H, yielding a fairly decent point cloud density. One is collecting the profile and striping of the roadway, and the other is collecting shoulder inventory to include signs, guardrail, delineators, foliage and rock faces. The E350 van also has a Trimble GPS (with inertial guidance), Applanix POS-LV, IMU and DMI equipment.

For data analysis, Arizona DOT uses Trident Analyst provided by Geo-3D (its vendor), a subsidiary of Trimble. The software allows Arizona DOT to handle all image processing and georeference any object that appears in two or more photos as well as lane or shoulder widths, sign dimensions and any polygon features such as potholes. Trident Analyst also uses LiDAR data for automatic sign extraction and polyline creation from roadway striping. Additional tools for LiDAR are available but Arizona DOT has not explored them to date.

For distribution, Arizona DOT has an in-house viewer that uses Windows Explorer with no add-ons to view the imagery. The external viewer requires a similar viewer using Windows Explorer as a backbone to the imagery.

2. Data Types and Distribution

Internal users can view 10+ years of data collection through the Arizona DOT intranet. The agency has a photolog server with over 70 TB of storage. Users can view 2004 through 2008 data at a single camera angle. For 2009 through 2014, both left and right views are available from the front of the collection van in high and low resolution. Arizona DOT created a low resolution of the imagery so that it can be streamed cleanly to numerous viewers simultaneously. Users can then select high-resolution images as needed for viewing.

External customers had the same viewer as internal customers through 2008. In 2009, Arizona DOT's annual database increased from 75 GB to 8 TB, and it was no longer practical to deliver a complete library. The agency has provided the entire highway system as a low-resolution, right-hand-camera-only viewer, which keeps the size to under 100 GB per year. The distribution is limited to business partners and consultants who need the data. The customer provides an external hard drive with 100+ GB per year requested, and Arizona DOT copies the information to the drive.

3. Emerging Technologies and Vendors

Arizona DOT has begun looking at the next generation of equipment. The agency would like to replace its current van, which was put into service in 2009 and has collected over 65,000 miles of data. Arizona DOT is looking at a variety of hardware and software vendors, including its current vendor Geo-3D/Trimble, Leica, Fugro Roadware and Immersive Media. It is also looking at options for combining these efforts with other statewide surveys.

Among the major advancements in technologies is LiDAR, which has become much more capable and cost-effective; Arizona DOT would like to enhance its current system with LiDAR. The agency is also looking at software that can better extract information from its photolog. The current system is proprietary, and distributing to multiple users can be cost-prohibitive and involve licensing issues. Trimble doesn't include a viewer for a larger audience, and its software doesn't process any data. (This must be done in-house or contracted out.) According to Arizona DOT, Connecticut DOT might have a contract with Fugro and Utah with Mandli, but Arizona DOT doesn't like the cost of the latter (approximately \$2 million). There is no plan for an update cycle, and the data will become outdated.

Arizona DOT calculated its costs per mile and said there are significant savings when performing the work in-house instead of hiring a contractor. Hiring a contractor to perform a roadway inventory is appropriate; but for special projects and ad hoc requirements, it's more cost-effective to do the project in-house. The agency gets requests related to road issues and landslides leading to data collection on a moment's notice. It would be difficult to find a contractor to collect the data for a reasonable cost. Arizona DOT's cost per centerline mile (both

lanes) is \$65, including manpower, cost of travel and vehicle maintenance—significantly less than what contractors would charge. But LiDAR extraction is not included, only photo imagery and processing. The agency's LiDAR application has been limited because of manpower. There is a cultural resistance to using LiDAR data instead of sending people into the field even though LiDAR requires less manpower, takes less time and is safer. There is a learning curve to feature extraction software, but it is not prohibitive.

4. Emerging Technology Adoption

Arizona DOT started using LiDAR in the 2009 collection with over 13,000 miles of data in the first year. The agency was the first DOT in the country to actively log its entire highway system with LiDAR. Arizona DOT continues to look at 360-degree photography and 360-degree LiDAR scanners with greater point cloud densities. (The current scanner has a 120-degree radius and misses items in the median as well as bridge clearances and overpasses. Newer scanners capture much more.) The agency is also considering combining its annual highway photolog survey with its profilometer (IRI) collection in the same vehicle.

5. In-House vs. Contract Work

All of Arizona DOT's work is done in-house. Its photolog team consists of two GIS technicians who schedule, collect, post-process and scrub all of the data. They also handle the entire database and file management necessary to produce the annual photolog. After they complete the yearly survey, the technicians give the data to Arizona DOT's information technology (IT) department, which manages the viewer for the data and runs the routines to link all of the data into a user-friendly geodatabase viewer through Windows Explorer. IT also creates the external version from the original data that Arizona DOT GIS technicians produced.

The only external cost to Arizona DOT is the software licensing, which includes technical support. Collecting data in-house is a matter of having flexibility, but requires a staff commitment. It is only cost-effective if there will be many years of consecutive, successive collection. If data are collected only once every 10 years, it is best to contract out the work since it is harder to stay technologically up to date doing things in-house because of the expense. Contractors have an economy of scale and can provide the latest technologies.

Asset extraction from data is a challenge—agencies can have great pictures, but it is labor-intensive to extract signs, shoulders and other features. This activity is more suited to a contractor. Arizona DOT recommends using a contractor to extract assets once for the state and then developing a plan for DOT staff to provide continued maintenance for data extraction. There's no reason to extract every feature every year when only 5 percent change. Automation of this process would help.

6. MAP-21

Currently the only asset that Arizona DOT uses the photolog for is the milepost inventory. Its software can extract any item that is in two consecutive photographs and apply an XY&Z. In addition, the LiDAR is capable of auto sign extraction, line-based inventory and a number of other tools that come packaged with the software. However, Arizona DOT has not pursued any additional feature extraction because of manpower. The agency only has a two-person team, and collecting and post-processing over 13,000 miles of data annually takes the better part of the year.

Again, the agency noted that culture can be a problem. Field crews can collect data in the field with handheld GPS (a monotonous and unsafe process) when 80 percent of the time they could be using photolog software. In addition to asset inventory, the photolog could be used for other business processes such as safety management. New LiDAR scanners could be used for retroreflectivity surveys.

7. Data Availability

The low-resolution right camera imagery is available but only by written agreement. Arizona DOT does not distribute or make available any of its data outside the agency except to consultants and business partners who demonstrate a need for the data. Before the agency releases the data, external users must sign a nondisclosure agreement stating that they will not use the data for profit, only for their business with Arizona DOT.

Connecticut

Contact: Robert Kasica, Data Collection Specialist, Bureau of Policy and Planning—Photolog, Connecticut Department of Transportation, 860-594-3153, robert.kasica@ct.gov.

Responses were received by email.

1. Technologies

CTDOT uses two Fugro Roadware ARAN vans, each outfitted with:

- A distance measurement instrument (an odometer), GPS and gyros for Position [and] Orientation Systems by Applanix.
- Ultrasonic grade sensors on the four vehicle corners, which are good for longitudinal grade but not good for cross grade due to rutting.
- An extendable rut bar with up to about 37 ultrasonic sensors available at four inches apart. Good cross slope is available from the rut bar because it spans beyond the rutted wheelpath.
- An inertial profiler consisting of lasers and accelerometers for IRI.
- One forward facing 90 degree FOV HDTV camera per van. A decade ago CTDOT had two SDTV or lesser digital to provide forward [and] side (almost panoramic/wide) combination. About four years ago, they had a successful test with a stereo HDTV camera setup (no photogrammetry) using a spare camera.
- Downward facing 2D pavement imaging systems. One van has analog cameras with strobe lighting captured into digital image. Another van has a 1mm scanning laser into a 2D digital image. Both are processed by using Roadware's WiseCrax software, all done in-house by CTDOT.

Processing and distribution are shown here:

<http://www.ct.gov/dot/cwp/view.asp?a=2857&q=332162>.

Analysis for quality control is done for various systems. Data [are] checked. Vans are run on control sites, and against each other. Pavement Management does a lot of the analysis on the pavement metrics. CTDOT [has] about 500 software installs on workstations. The data and images come off the server via the intranet. Unfortunately, CTDOT doesn't have an Internet-based image viewing capability.

Further information about CTDOT's program is located here:
<http://www.ct.gov/dot/cwp/view.asp?a=2857&q=438418>.

2. Data Types and Distribution

All data [are] available to everyone. CTDOT has about 500 software installs on workstations. The data and images come off the server via the intranet. Other people or agencies not on the intranet can have standalone copies. A full copy of the state routes with data is about 1TB. Most users are DOT. A number a non-DOT state agencies have received copies including state police, emergency management, [department] of environmental protection, state library, regional planning agencies, etc. Non-state users are engineering design firms, lawyers, crash investigators, etc.

Pavement Management does the pavement-related metrics. The other analysis would be done by various other units in their tasks. Photolog actually doesn't have a full handle on how exactly all of the data [are] used and analyzed by others. Photolog does track how much use [they get] over the intranet in order to calculate cost savings by trips not taken to the field by other personnel.

Roadway Inventory Systems reports road quality and key geometrics data items to the [Federal Highway Administration (FHWA)] every year.

At CTDOT, Photolog is currently down to a four person operation, and it [has] been a producer of data but not a consumer or aggregator of data. So it pushes data out but does not take [data] in, and thus is unfamiliar with the final uses of Photolog. CTDOT's traffic group is using Photolog for an FHWA-required project to inventory its signs, which will allow the department to manage highway sign retro-reflectivity levels and develop a highway sign asset management program.

3. Emerging Technologies and Vendors

CTDOT has looked into technologies like LiDAR and photogrammetry. However, without financial commitments from some end users, purchases and implementation will not happen. The most significant advance CTDOT will have (probably) is the 3D scanning lasers by Pavemetrics.

Acquisition of new instruments or cameras or maybe a third van for collecting the municipal roads will probably be driven more by internal CTDOT department needs than outside unfunded suggestions. There is a possibility that the local municipal roads can be done by an outside vendor sometime in the future. If CTDOT Photolog does the locals, it may end up using Fugro Roadware's Vision software because there's a straight line diagram option available. Straight line diagrams are still used by some CTDOT units, but it's hard to say what shape they are currently in.

4. Emerging Technology Adoption

The most significant advance CTDOT will have (probably) is the 3D scanning lasers by Pavemetrics.

5. In-House vs. Contract Work

CTDOT performs in-house data collection, data quality control analysis and distribution. Other data extraction analysis is performed by various other units. Sometimes something can be contracted out such as signage extraction. Most of Photolog processing and viewing software

has been created by a long-term consultant. At one time CT was a leader in early implementation.

6. MAP-21

Various units do have their inventory items. Roadway Inventory Systems, AKA Planning Inv. & Data, reports the items required by FHWA and they would be most familiar with the specifics of MAP-21:

- Al Iallonardo, Transportation Supervising Planner, Inventory and Forecasting, 860-594-2107, al.lallonardo@ct.gov.
- Facundo Dominguez, Transportation Planner 2, Planning Inventory and Data, 860-594-2113, facundo.dominguez@ct.gov.
- James Spencer, Transportation Supervising Planner, Inventory and Forecasting, 860-594-2014, james.spencer@ct.gov.
- Edgardo Block, Transportation Supervising Engineer, Pavement Management, 860-594-2495, edgardo.block@ct.gov.

Until the Feds issue some particular orders, CTDOT is not likely going to be particularly proactive about upgrading Photolog without new funding.

7. Data Availability

Data [are] available outside of CTDOT. Firms and individuals request images and data. CTDOT provides it upon request. Luckily, they don't have sensitive data thus don't have to clear it with anyone. CTDOT's Legal Affairs people are notified of all requests and the non-DOT Department of Homeland Security and Emergency Management knows that it distributes freely to the public.

Maryland

Contact: John Andrews, Assistant Division Chief, Field Exploration Division, Maryland State Highway Administration, 443-572-5177, jandrews@sha.state.md.us.

Responses were received by email.

1. Technologies

MSHA currently uses ultra-high definition digital images from two calibrated cameras. The primary has a high accuracy 90-degree lens and is aimed slightly to the shoulder. The secondary has a 60-degree lens and is aimed towards the median. These take photos every 21 ft.

2. Data Types and Distribution

The images for the past several years are available to all with intranet access in the Maryland State Highway Administration.

3. Emerging Technologies and Vendors

MSHA plans to stay with these images for right-of-way management for the near future at least. Triangulation processes locate the assets within its requirements at this time.

4. Emerging Technology Adoption

No.

5. In-House vs. Contract Work

Work is performed in-house.

6. MAP-21

MSHA currently does so.

7. Data Availability

The data [are] available outside MSHA but I am not sure of the processes involved.

Minnesota

Contact: David Janisch, Pavement Design Engineer, Minnesota Department of Transportation, 651-366-5567, dave.janisch@state.mn.us.

Responses were received by email.

1. Technologies

MnDOT collects photolog images with the same van that it uses to measure pavement roughness/rutting (Pathway Services Pathrunner). The vehicle captures front-right perspective images as well as down-looking 3D images.

2. Data Types and Distribution

MnDOT copies the front and right perspective images to a central server and then they are available to all DOT employees via a CITRIX Server.

3. Emerging Technologies and Vendors

The vendor does have web version but I believe they must host the data/images. We have not explored that option in any great detail.

4. Emerging Technology Adoption

Viewing the images via a CITRIX Server is the latest new thing MnDOT has done related to photolog.

5. In-House vs. Contract Work

All done in-house.

6. MAP-21

MnDOT assesses pavement cracking/condition using the 3D images from the van. To my knowledge, it is not used for any other type inventory, such as signs, etc.

7. Data Availability

If requested, MnDOT provides the images on a portable hard drive (furnished by the requestor). Since the viewing software is proprietary, they must buy that from the vendor (Pathway Services, Inc.).

Tennessee

Contact: Jeff Murphy, Information Systems Manager, Tennessee Department of Transportation, 615-741-3429, jeff.murphy@tn.gov.

Responses were received by telephone.

1. Technologies

Tennessee DOT uses front- and side-view cameras using a contractor (in the past, Mandli) on a two-year cycle. The contractor collects data for half the state each year, and typically collects other data when doing photolog, such as pavement conditions and maintenance assets. The cost is \$60 per mile.

For data analysis and distribution, Tennessee DOT uses a web-based application developed by Intergraph (owned by Hexagon). It streams lower resolution thumbnails, but a full-resolution image can be brought up on command. The application is linked to an eTRIMS mapping application, where users can do ad hoc queries against the data.

2. Data Types and Distribution

Access is only internal to Tennessee DOT.

Data include route features, maintenance features and asset management features such as signs and guardrails. These are also tied to a linear referencing system for logging miles.

3. Emerging Technologies and Vendors

In the past, Mandli has collected data using LiDAR, and Tennessee DOT has extracted assets from that data. But currently Tennessee DOT only uses photography.

4. Emerging Technology Adoption

No.

5. In-House vs. Contract Work

All work is done under contract, not in-house.

6. MAP-21

No.

7. Data Availability

The data are not available to the public, but they are available to city governments and contractors. Doing so helps keep the data accurate. (A city can provide a correction, for instance, if there is an error in the data.) State government gets sued frequently, and archived

photologs can provide needed evidence. Access to photolog data is provided via a web-based application, ImageViewer, that was custom-developed for Tennessee DOT by Integraph.

Utah

Contact: Stan Burns, Director of Asset Management, Utah Department of Transportation, 801-633-6221, sburns@utah.gov.

Responses were received by telephone.

1. Technologies

Utah DOT has an extensive photolog program using both LiDAR and high definition images. They use mobile LiDAR fencepost to fencepost and can geospatially locate everything. Their photolog is tied in with all their business systems, and a user can see an image of any road from any business system. Utah DOT does quite a bit of analysis with its full data set, for the purposes of asset management, safety and design. They've been using a contractor for seven years – initially Mandli, then Fugro, and then back to Mandli, with whom they have a six year contract to collect both features and pavement distress data on every even year.

2. Data Types and Distribution

The data are available to the public without a login at <http://data.udot.utah.gov>.

3. Emerging Technologies and Vendors

Three years ago, Utah DOT invited software companies, including Mandli, Oracle, Esri, Deighton, 3M and Virtual Geomatics, to collaborate on helping to build a system. These companies weren't paid, but could resell their products. Esri worked with AAA Technologies to develop a safety management system linking crashes with assets. Oracle and Deighton helped build the beginnings of a data warehouse. 3M and Virtual Geomatics tried to find a correlation between the intensity of LiDAR and retroreflectivity. Mandli offers mobile grade mapping, which is great for assets with an accuracy of +/- 5 feet absolute and +/- 2cm relative. This can be used for asset inventory, maintenance, safety operations, concept level reporting, clear zones and vertical clearance. Utah DOT has used it on half a dozen projects. Working with a survey company called Meridian, the agency calibrated the point cloud from mapping to survey grade. Utah DOT has designed a couple of projects using the point cloud.

4. Emerging Technology Adoption

See No. 3.

5. In-House vs. Contract Work

Utah DOT does almost all data collection with private industry, although it collects crash and traffic data itself. It organizes this data within its mapping system, UPLAN (<http://uplan.maps.arcgis.com/home/>). Many of its staff, especially its younger staff versed in programming, is using this data for analyses, including safety, design and life-cycle cost analyses. For example, the staff determined how to extract sloped guardrails from the photolog, where in the past, maintenance would have had to drive all roads with clipboards and pencil and paper.

6. MAP-21

Utah DOT has a complete, geospatially located inventory, for example, of its 97,000 signs with data on height, width and road offset.

7. Data Availability

The data are available to the public without a login at <http://data.udot.utah.gov>, which is convenient for consultants and many other users. For example, billboard vendors built a website using this data and they can easily tell which are compliant.

Utah DOT has provided an RFP, data dictionary and contractor for its system to at least 20 states. (See [Appendices A, B and C](#), respectively, for these documents, or <https://www.udot.utah.gov/public/ucon/uconowner.gf?n=16644326445562179>.) Five states seem to have made use of these in their own systems. Utah DOT does not specify mobile LiDAR, but the requirements (± 1 -foot accuracy over 50 feet) will drive users to this. Photographs don't have that accuracy. For now, LiDAR is cutting edge.

Eight or nine states have UPLAN, which organizes the data in a geospatial environment on a map so it can be seen. The biggest barrier to implementation is not organization in UPLAN but getting accurate information. Many states have information collected ad hoc by different groups with different standards and requirements. Some data are very suspect. Once the data are accurate and organized, the next biggest challenge is to find staff capable of analyzing it. Working with Oracle, Utah DOT is trying to create a data warehouse to link the information spread out between various databases, such as project development, construction, materials and asset management. Many states would like to do something similar. This would enable comprehensive analyses, for example, to correlate design, materials, condition, construction tests and contracting information for a given road to find patterns that explain the road's current condition (possibly relating it to a certain contractor or material pit). A similar analysis could be made with safety data, relating crashes to weather, friction, roadway curvature and other factors.

Consultation with Vendors

We contacted two vendors of photolog-related services by phone.

Fugro

Contacts: Damion Orsi, Product Manager, Fugro Roadware, 905-567-2870, dorsi@fugro.com.

Martin Kodde, Research and Development Manager, Fugro DRIVE-MAP, 31-0-70-3170928, m.kodde@fugro.nl.

When it comes to the development of innovative technologies, LiDAR is making advances in resolution. Orsi recommended the Washington State report LiDAR for Data Efficiency (see Related Research and Resources) for a comparison of relatively new technologies and their costs. LiDAR is good for project-level collection, but it takes a lot of work to get engineering-grade resolution. It's a matter of how much money a DOT is willing to spend and what resolution it needs. Some agencies would like stationary LiDAR data on a network

level with mobile LiDAR, which requires absolute accuracies that are sufficient for engineering decisions, requiring a very high resolution. Ultimately, the trend for the technology is toward higher resolution with faster frequencies so that a vehicle can travel at 65 mph and still get as many accurate points as a stationary LiDAR.

High-resolution photogrammetry is still more cost-effective than LiDAR, and the high resolution of LiDAR isn't required for most asset management needs. Fugro performs asset collection for a number of DOTs, including Louisiana Department of Transportation and Development, Virginia DOT and Pennsylvania DOT. Photographic data also take much less space to store than LiDAR data, which saves DOTs the large cost of storing the extra data. However, either system has its pros and cons, and deciding what technology gets used depends on the client's needs and requirements.

Mandli

Contact: John Caya, Vice President of Business Development, Mandli Communications, Inc., 608-835-3500, ext. 1001, caya@mandli.com.

Mandli has been collecting photolog data for over 30 years, with imagery tied to GPS and linear reference data and capable of having roadside features extracted.

LiDAR provides a higher resolution and 3D point cloud. It makes it easier to automate the process of extracting assets and asset conditions. For example, it can provide the surface area of road signs, which can be used to calculate material costs for replacing signs. It can also be exported to design or GIS, allowing for example analyses of the relationship between traffic accidents and road geometry or conditions. LiDAR is also generally easier to collect than photogrammetry since there is no problem when the sensor is facing into the sun. As for the largeness of the data sets, data can be compressed so that they can be distributed over the web or accessed through the cloud. Quite a bit of data extraction can be automated—in some cases, even sign conditions. (LiDAR intensities can be correlated to reflective pavement stripe and sign conditions.) In other cases, manual extraction work is required where a condition assessment is more subjective and requires staff to look at imaging, or in certain measurements, such as cross-slope.

For more information about mobile LiDAR, Caya recommends contacting Gene Rowe of TRB and Paul Carlson of the Texas Transportation Institute. He will provide CTC with their contact information as well contact information for potential interviewees at European transportation agencies.

Related Research and Resources

Mobile LiDAR

Implementation of Aerial LiDAR Technology to Update Highway Feature Inventory, Utah Department of Transportation, End date: July 2017.

<http://www.mountain-plains.org/research/projects/downloads/2014-mpc-462.pdf>

This ongoing project is exploring Aerial LiDAR as a more cost-effective means of updating its feature inventory than mobile LiDAR. *From the Research Needs statement:*

Aerial LiDAR technology offers the advantages of a) less time spent in data collection (days rather than months), and b) a view of the roadway from a different perspective, allowing features to be viewed and identified that may have been hidden from the Mobile platform. A possible disadvantage may be lower resolution of the point cloud (fewer data points per square meter). This project is to test whether Aerial LiDAR data can be a) obtained accurately and quickly enough to be cost-effective as compared to a second Mobile run, b) successfully merged with the Mobile LiDAR point cloud such that differences in the asset inventory can be easily identified, and c) used as a tool to identify features that were not visible from the Mobile platform.

Application of New Technologies to Improve Risk Management, Austroads, July 2014.

<http://www.onlinepublications.austroads.com.au/items/AP-T268-14>

From the abstract: Austroads project AT1539 developed guidance for the use of new technologies that can improve the efficiency of road asset managers. This report is the second stage of the project and it assesses eleven new technologies that can be potentially useful for road asset managers. Each technology is described in terms of its concepts, physical principles, potential use in asset management and any limitations, case examples and, for level 1 and 2 priority technologies, standards and insights on the costs of the technology. The technologies are mapped to different asset management aspects. This mapping shows the type of data that is collected, which information is obtained and for which asset management aspect this information is used. Additionally, conclusions are drawn on how to deploy each technology based on the potential use in asset management, market readiness, the quality of the provided data and the costs and business case considerations. In particular, LiDAR technology was assessed to have a significant potential for road asset management. Potential applications and issues have been discussed in dialogue between road agencies and LiDAR industry stakeholders. This resulted in a separate discussion paper describing best practice for mobile LiDAR survey requirements.

“Considerations for Effective LiDAR Deployment by Transportation Agencies,” Jeffrey Chang, Daniel Findley, Christopher Cunningham, Mary Tsai, *TRB 93rd Annual Meeting*, 2014.

<http://docs.trb.org/prp/14-0256.pdf>

From the abstract: The methodology presented in this paper aims to provide guidance on how agencies may determine whether or not LiDAR can be practically utilized within their organizations. It is recommended that interested parties systematically consider the aspects and performance measures outlined for effective deployment of LiDAR equipment or contracted services.

NCHRP Report 748: Guidelines for the Use of Mobile LiDAR in Transportation Applications, Michael Olsen, Gene Roe, Craig Glennie, Fred Persi, Marcus Reedy, David Hurwitz, Keith Williams, Halston Tuss, Anthony Squellati, Michael Knodler, 2013.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_748.pdf

This report presents guidelines for applying mobile 3D LiDAR technology to state DOT operations. It includes comprehensive chapters on applications, workflow and data management, procurement and implementation. Chapter 17, Emerging Technologies, presents technological advancements, including an increase in scanner range, speed, accuracy and portability; systems integration; 3D point cloud reconstruction from 2D images; and Flash LiDAR.

Utilization of Mobile LiDAR to Verify Bridge Clearance Heights on the Western Kentucky Parkway, Brad Rister, Levi McIntosh, Joe Whelan, Kentucky Transportation Center, August 2013.

http://www.ktc.uky.edu/files/2013/08/KTC_13_09_FRT_199_13_1F.pdf

From the abstract: Bridge clearances can vary from lane-to-lane beneath overpasses, and can often be difficult to measure due to high traffic volumes. Therefore, a mobile LiDAR unit was utilized in this project to obtain the bridge clearance heights on the Western Kentucky Parkway. The LiDAR information was collected at 400,000 points-per-second at a driving speed of 30 mph. Hand measurements were also taken on each bridge to assist in quantifying the potential error between field measurements and LiDAR measurements. The results of the collected LiDAR data appear to be less than 1.2 inches, which appears to be in line with both manufactures and industry standards.

“Evaluation of Remote-Sensing Technologies for Collecting Roadside Feature Data to Support Highway Safety Manual Implementation,” Mohammad Jalayer, Jie Gong, Huaguo Zhou, Mark Grinter, *TRB 92nd Annual Meeting Compendium of Papers*, Paper #13-4709, 2013. Abstract at: <http://trid.trb.org/view/2013/C/1242774>

From the abstract: Roadside feature data are critical inputs to highway safety models as described in the Highway Safety Manual (HSM). Collecting safety-related roadside feature data is an important step for HSM implementation. Many state DOTs routinely collect data on roadside objects using a variety of sensing methods, and these programs often incur significant cost. At present, it is unknown which of these methods or any combination of these methods is capable of efficiently collecting safety-related roadside feature data while minimizing cost and safety concern. The objective of this research is to identify required roadside feature data for various types of highway segments and to characterize the capability of existing sensing methods in contrast to required roadside feature data through literature review and a nationwide survey, and large-scale field trials of selected sensing methods. The results of literature review and surveys are reported in this paper. The findings of this research suggest that either mobile LiDAR or the combination of video/photo log method with aerial imagery method is capable of collecting required HSM-related roadside information. However, due to the high data reduction effort, the current mobile LiDAR method needs significant improvement in the LiDAR data processing and feature extraction stage.

Investigation of Methods and Approaches for Collecting and Recording Highway Inventory Data, Huaguo Zhou, Mohammad Jalayer, Jie Gong, Shunfu Hu, Mark Grinter, Civil Engineering Studies, Illinois Center for Transportation Series, 2013.

Abstract at: <http://trid.trb.org/view/2013/M/1278486>

From the abstract: Many techniques for collecting highway inventory data have been used by state and local agencies in the United States. These techniques include field inventory, photo/video log, integrated global positioning system/geographic information system (GPS/GIS)

mapping systems, aerial photography, satellite imagery, virtual photo tourism, terrestrial laser scanners, mobile mapping systems (i.e., vehicle-based light detection and ranging (LiDAR), and airborne LiDAR). These highway inventory data collection methods vary in terms of equipment used, time requirements, and costs. Each of these techniques has its specific advantages, disadvantages, and limitations. This research project sought to determine cost-effective methods to collect highway inventory data not currently stored in Illinois Department of Transportation (IDOT) databases for implementing the recently published Highway Safety Manual (HSM). The highway inventory data collected using the identified methods can also be used for other functions within the Bureau of Safety Engineering, other IDOT offices, or local agencies. A thorough literature review was conducted to summarize the available techniques, costs, benefits, logistics, and other issues associated with all relevant methods of collecting, analyzing, storing, retrieving, and viewing the relevant data. In addition, a web-based survey of 49 U.S. states and 7 Canadian provinces has been conducted to evaluate the strengths and weaknesses of various highway inventory data collection methods from different state departments of transportation. To better understand the importance of the data to be collected, sensitivity analyses of input variables for the HSM models of different roadway types were performed. The field experiments and data collection were conducted at four types of roadway segments (rural two-lane highway, rural multi-lane highway, urban and suburban arterial, and freeway). A comprehensive evaluation matrix was developed to compare various data collection techniques based on different criteria. Recommendations were developed for selecting data collection techniques for data requirements and roadway conditions.

LiDAR for Data Efficiency, Kin Yen, Bahram Ravani, Ty Lasky, Washington State Department of Transportation, September 2011.

<http://www.wsdot.wa.gov/research/reports/fullreports/778.1.pdf>

From the abstract: The research objective was to evaluate mobile LiDAR technology to enhance safety, determine efficiency gains, accuracy benefits, technical issues, and cost benefits of using this technology with a focus on collection, processing, and storage of the data into current WSDOT business processes. A field pilot study was conducted to collect empirical data for feasibility evaluation and cost benefit analyses. While the pilot study demonstrated the potential positive impact in WSDOT business processes, it also highlighted the need for best practices documentation for using mobile LiDAR for DOT to ensure consistent and accurate results. Details of data collection methods and cost for WSDOT Roadside Feature Inventory Program (RFIP), bridge clearance measurement, and ADA feature inventory were gathered. These programs would achieve direct cost saving in deploying mobile LiDAR system. Cost benefit analyses of seven mobile LiDAR deployment options are presented. Purchasing and operating a survey grade mobile LiDAR system produced the highest savings of \$6.1 million in six years. Although deploying the survey grade mobile LiDAR system costs more, the benefits and cost saving from the bridge clearance operation and ADA feature inventory outweighs the higher cost and produces higher saving. Mobile LiDAR technology lowers the number of FTEs, vehicles, and carbon dioxide emissions for data collection. The major intangible benefactors are WSDOT's GeoMetrix Office, Geotechnical Office, Planning Office, Environmental Office, and Attorney Generals (AG) Office. The technology could also be useful in other state agency application areas such as cultural heritage preservation, homeland security, construction inspection, and machine guidance in construction. Deployment of a mobile LiDAR system is recommended.

Mobile Photographic Imaging

Monitoring Highway Assets with Remote Technology, Michigan Department of Transportation, July 2014.

http://www.michigan.gov/documents/mdot/RC-1607_466453_7.pdf?20140826130444

This pilot project evaluated several remote technologies for monitoring highway assets, including mobile photographic imaging by Fugro and mobile LiDAR imaging by Mandli as well as aerial and mobile LiDAR by AeroMetric. It concludes that (*from the abstract*):

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

Pages 56-77 summarize the results of various methods and vendors, and page 77 provides a cost per trunk mile analysis of each.

Pages 26-28 review DOT GIS systems built from commercial off-the-shelf software, and pages 28-30 review custom systems.

“Automation Techniques for Digital Highway Data Vehicle (DHDV),” Kelvin Wang, Zhiqiong Hou, Weiguo Gong, *Seventh International Conference on Managing Pavement Assets*, 2008.

<http://www.pavementmanagement.org/ICMPfiles/2008054.pdf>

From the abstract: This paper describes the development of a real-time multi-functional system for roadway data acquisition and analysis, particularly for pavement surface distress survey and roadside asset management. This system, Digital Highway Data Vehicle (DHDV), combines the technologies of laser illumination based digital imaging, inertial profiling and Global Positioning System (GPS) mapping into an integrated system to accomplish the multiple tasks of survey and management for roadway data. The resolution of the pavement images is 1-mm in both longitudinal and transverse directions with the use of high resolution line cameras covering the entire pavement of a single lane. The pavement distress analysis and road sign inventory can be conducted in real time. The system utilizes pattern recognition, image analysis technique and target tracking for performing multiple tasks through parallel processing. Algorithms are presented with the emphasis on the real-time processing of raw data streams in a parallel array of processing cores.

“A Roadway Photolog Goes High-Definition: Connecticut Expands User Network, Realizes Cost Savings,” Bradley Overturf, *TR News*, Issue 254, pages 3-9, January-February 2008.

<http://onlinepubs.trb.org/onlinepubs/trnews/trnews254.pdf>

From the abstract: The Connecticut Department of Transportation (DOT) has created a high-definition image inventory of the state's entire roadway network, accessible for desktop computer viewing by users throughout the agency. In this article the Connecticut DOT's photolog director traces the development and capabilities of the pioneering system, which has saved the state approximately \$2 million.

Data Extraction, Software and Modeling

Use of Traffic Speed LiDAR in Road Asset Management, D Wright, G Crabb, A Gleeson, Transport Research Laboratory, 2014.

http://www.trl.co.uk/umbraco/custom/report_files/PPR694.pdf

This report investigates the use of LiDAR for the measurement and assessment of road assets, specifically the automation of asset assessment using algorithms for the location and measurement of roadside barriers, bridges and gantries. Testing showed the algorithm capable of identifying 80 percent of barriers with an accuracy of ± 5 cm.

Development of the ConnDOT Horizontal Curve Classification Software, Abigail Osei-Asamoah, Eric Jackson, Connecticut Department of Transportation, 2014.

http://www.ct.gov/dot/lib/dot/documents/dresearch/CT-2285-F-14-3_Published_Final_Report.pdf

From the abstract: The Highway Performance Monitoring System (HPMS) is a national, highway information system that requires states to collect and submit data on the extent, condition, performance, use, and operating characteristics of the nation's highways. HPMS requirements include limited data on all public roads, with more detailed data for sample sections of the arterial and collector functional classes. One of the field inventory reviews that many states have a difficult time reporting efficiently is the required horizontal curve classification for each HPMS section. Connecticut has more than 2000 HPMS sites making manual updates to these sections very difficult and time consuming. Automated methods to create a batch reporting process could save significant time and effort while increasing the accuracy with which data are reported to the Federal Highway Administration (FHWA). Connecticut is fortunate in that the department of transportation performs an annual photolog survey of all state roads and conducts supplemental data collection runs for HPMS sections. This report details the creation of an automated curve classification software kit to generate grade and horizontal curve classification files for HPMS reporting.

Use of Low-Cost Remote Sensing for Infrastructure Management, Su Zhang, Susan Bogus, Construction Research Congress 2014, pages 1299-1308, May 2014.

Abstract at: <http://trid.trb.org/view/2014/C/1309154>

From the abstract: Many owner organizations use manual, visual methods for evaluating the condition of infrastructure. However, manual, visual evaluation is labor intensive, time consuming, and potentially dangerous. Advances in remote sensing technology, such as high-resolution, multispectral digital aerial photography and high-resolution airborne laser radar (LiDAR) provide new methods for collecting condition information on infrastructure assets that can be used for infrastructure management. To evaluate the potential for using remote sensing technology for infrastructure management, the authors compared data extracted from aerial photos and LiDAR with reference data on pavement surface conditions that were collected manually. The statistics of the spectral response of the bands within the digital aerial photographs and the elevation within the airborne LiDAR were extracted and correlated to the

reference data using stepwise linear regression models. The results show that the spectral response in digital aerial photographs of 0.1524-m (6-in.) resolution and 1-m resolution with an infrared band closely match the reference data. The results also show that the elevation response in airborne LiDAR of 1-m resolution closely match the reference data. These results open the way for the future use of digital aerial photographs and LiDAR to assess the infrastructure system conditions remotely.

“Road Extraction from LiDAR Data Using Support Vector Machine Classification,” Ali Akbar Matkan, Mohammad Hajeb, Saeed Sadeghian, *Photogrammetric Engineering and Remote Sensing*, Vol. 80, Issue 5, pages 409-422, May 2014.

http://www.asprs.org/a/publications/pers/2014journals/PERS_May2014_Flipping/HTML/index.html#408

From the abstract: This paper presents a method for road extraction from LiDAR data based on support vector machine (SVM) classification. The LiDAR data are used exclusively to evaluate the potential in the road extraction process. First, the SVM algorithm is used to classify the LiDAR data into five classes: road, tree, building, grassland, and cement. Then, some misclassified pixels in the road class is removed using the road values in the normalized Digital Surface Model and Normalized Difference Distance features. In the post-processing stage, a method based on Radon transform and Spline interpolation is employed to automatically locate and fill the gaps in the road network. The experimental results show that the proposed algorithm for gap filling works well on straight roads. The proposed road extraction algorithm is tested on three datasets. An accuracy assessment indicated 63.7 percent, 60.26 percent and 66.71 percent quality for three datasets. Finally, centerline of the detected roads is extracted using mathematical morphology. Road information plays an important role in many modern applications, including transportation, automatic navigation systems, traffic management, and crisis management, and enables existing geographic information system (GIS) databases to be updated more efficiently. In the past two decades, automatic road extraction has become an important topic in remote sensing, photogrammetry, and computer vision. In addition, recent advances in LiDAR systems and their enormous potential in automatic feature extraction motivate the development of automatic road extraction algorithms based on LiDAR data.

“Mobile Cross-Slope Measurement Method Using LiDAR Technology,” Yichang Tsai, Chengbo Ai, Zhaohua Wang, Eric Pitts, *Transportation Research Record 2367*, pages 53-59, 2013.

Abstract at: <http://trid.trb.org/view/2013/C/1242802>

From the abstract: The proposed mobile cross-slope measurement method uses emerging LiDAR technology (LiDAR calibration, data acquisition, region of interest extraction, and cross-slope computation). A sensitivity study was conducted to determine the key parameter (i.e., the region of interest interval) for the proposed method. The accuracy and the repeatability of the proposed method were critically validated through testing in a controlled environment. A case study demonstrated the capability of the proposed method. The results from the controlled test show that the proposed method can achieve desirable accuracy with an average measurement difference of 0.08° from the digital-level measurements and a desirable level of repeatability with a standard deviation of less than 0.03° in three runs. The results of the case study show that the proposed method can be operated at highway speed and is promising for the assessment of network-level cross-slope adequacy.

Automatic Network-Level Identification of Sight Distance Values from Existing Datasets, Kelvin Santiago-Chaparro, Madhav Chitturi, Andrea Bill, David Noyce, *TRB 92nd Annual Meeting*, Paper #13-0054, 2013.

<http://docs.trb.org/prp/13-0054.pdf>

From the abstract: This paper focuses on the use of existing photographic logs commonly owned by transportation agencies to automate the process of computing the sight distance available, from a vertical alignment point of view, along an entire route. While the analysis presented is focused on identifying road segments in need of a no passing zone, results from the methodology discussed can also be used to identify segments where advisory speeds need to be established, as well as those segments where posted speeds should be increased/decreased in order to improve safety. Through the application of the methods presented in this paper, the authors demonstrate how value can be added to existing datasets that were originally collected for completely different purposes.

Critical Assessment of Automatic Traffic Sign Detection Using Three-Dimensional LiDAR Point Cloud Data, Chengbo Ai, Yichang Tsai, *TRB 91st Annual Meeting Compendium of Papers DVD*, Paper #12-3214, 2012.

Abstract at: <http://trid.trb.org/view/2012/C/1130173>

From the abstract: This paper is the first that critically assesses the use of an automatic method for traffic sign detection using 3D LiDAR point cloud data in support of traffic sign inventory. The contribution of this paper is three-fold: 1) it presents an automatic method for traffic sign inventory using 3D LiDAR point cloud data; 2) it critically assesses the performance of the presented method in terms of detection rate and false negative/false positive cases; 3) it suggests the adequate parameter values to achieve a good traffic sign detection rate. Actual data, collected on Interstate 95 (major arterial) and 37th Street in Savannah, Georgia (local road), is used to assess the performance. Results show that the presented method can correctly detect 94.0% and 91.4% of the traffic signs on both roadways, respectively, with less than 7 false positive cases. The results demonstrate that the presented method using 3D LiDAR point cloud data is promising for traffic sign inventory. Future research directions are recommended.

“Automated Extraction of Road Markings from Mobile LiDAR Point Clouds,”

Photogrammetric Engineering and Remote Sensing, Bisheng Yang, Lina Fang, Qingquan Li, Jonathan Li, Vol. 78, Issue 4, pages 331-338, April 2012.

Abstract at: <http://trid.trb.org/view/2012/C/1137253>

From the abstract: This paper proposes a method for extracting road markings from mobile LiDAR point clouds. Among implicit information of laser points, the strength of reflection of laser points is closely related to the property of road materials that helps in detecting road markings. An interpolation method is used first in order to generate a georeferenced feature image of the point clouds, which helps to isolate the points of road surfaces. An algorithm is used to separate these points within a range according to their strength of reflection. The separated points are further segmented to remove non-road points based on their height threshold. The outlines of road markings are extracted from the segmented points using the semantic knowledge of road markings. The results presented in the paper demonstrate that the method used was very promising for automatic extraction of road markings from LiDAR point clouds collected by a land-based mobile LiDAR system.

Contacts

CTC contacted the individuals below to gather information for this Preliminary Investigation.

State Agencies

Arizona

James Meyer
GIS Program Manager
Arizona Department of Transportation
602-712-8037, jmeyer@azdot.gov

Robert Bush
Transportation Photolog Specialist
Arizona Department of Transportation
602-712-7248, ext. 8590, rbush@azdot.gov

Connecticut

Robert Kasica
Data Collection Specialist
Bureau of Policy and Planning—Photolog
Connecticut Department of Transportation
860-594-3153, robert.kasica@ct.gov

Maryland

John Andrews
Assistant Division Chief, Field Exploration
Division
Maryland State Highway Administration
443-572-5177, jandrews@sha.state.md.us

Vendors

Fugro

Damion Orsi
Product Manager
Fugro Roadware
905-567-2870, dorsi@fugro.com

Martin Kodde
Research and Development Manager
Fugro DRIVE-MAP
31-0-70-3170928, m.kodde@fugro.nl

Minnesota

David Janisch
Pavement Design Engineer
Minnesota Department of Transportation
651-366-5567, dave.janisch@state.mn.us

Tennessee

Jeff Murphy
Information Systems Manager
Tennessee Department of Transportation
615-741-3429, jeff.murphy@tn.gov

Utah

Stan Burns
Director of Asset Management
Utah Department of Transportation
801-633-6221, sburns@utah.gov

Mandli

John Caya
Vice President of Business Development
Mandli Communications, Inc.
608-835-3500, ext. 1001, caya@mandli.com