Geospatial Highway Inventory and Traffic Safety Applications: A Survey of State Practice and Software Solutions

Requested by
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The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI 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.

Executive Summary

Background

Signed into law in 2012, MAP-21, the Moving Ahead for Progress in the 21st Century Act, requires that a state have in place a safety data system that can be used to perform analyses supporting strategic and performance goals in the state's Strategic Highway Safety Plan and Highway Safety Improvement Program. The new law also requires states to use their safety data systems to identify fatalities and serious injuries on all public roads by location, and specifies that states have the capability to link crash, roadway and traffic data by geolocation.

Caltrans is seeking to update or replace its Transportation System Network (TSN) and Traffic Accident Surveillance and Analysis System (TASAS) to meet the MAP-21 requirements and other critical agency needs. The TSN is a departmental database application used for maintaining and linking traffic census, collision data and highway inventory data. It also serves as the base information system for all traffic safety analysis. Caltrans' TASAS Branch maintains the TSN application with highway inventory fields for all state highway facilities in California. The TASAS Branch also maintains accident data in the TSN system for all collisions on or associated with a state highway facility.

This Preliminary Investigation aims to support Caltrans' effort to update its TSN/TASAS database by gathering information from other state departments of transportation (DOTs) about their experience with existing or planned geospatial highway inventory and traffic safety applications. We also completed a limited evaluation of software solutions that geolocate and analyze crashes to augment this information.

As a follow-up effort to this Preliminary Investigation, Caltrans requested additional information on two key elements for developing effective asset management and safety management programs—geospatially enabled highway inventory and traffic data. The results of interviews conducted with three state transportation agencies on these topics are presented in Appendix A.

Summary of Findings

To gather information about other states' experiences with geospatial highway inventories and traffic safety analysis tools, we contacted eight state DOTs expected to have experience with existing tools or plans to develop them. We also examined the nonproprietary geolocation or traffic safety analysis tools used by some of these states.

This Preliminary Investigation is organized into two sections, described below:

- State Practices.
- Crash Location and Analysis Software.

State Practices

We interviewed representatives from eight state DOTs—Arkansas, Florida, Michigan, Minnesota, North Carolina, Ohio, Texas and Washington—and summarize those discussions and related resources in the following topic areas:

- Background.
- System description, functionality and use.
- Data analysis.
- Development and implementation.
- System maintenance.
- System access.
- What's next.
- Related resources.
- Contacts.

Four of the eight states interviewed for this Preliminary Investigation have initiated efforts to replace existing traffic safety analysis tools or indicate that such an effort may begin:

- In Florida, discussions are underway to move from Florida DOT's current tool, which is based on a linear referencing system (LRS), to a practice based on geographic information system (GIS) processes. FDOT is interested in developing a tool that can serve its needs as well as those of local agencies throughout the state.
- Michigan DOT is planning to replace its Safety Management System, developed in 1993 and updated in 1996. MDOT expects to begin developing a new system in six months.
- In Minnesota, a 2011 research report that examined the traffic safety analysis tools used in other states laid the groundwork for MnDOT's continuing project to replace its Transportation Information System, a mainframe database developed more than 30 years ago that does not allow for geospatial location and crash analysis. MnDOT hopes to have a new crash database implemented by January 2015, with crash analytics available later that year.
- North Carolina DOT is considering replacing its Traffic Engineering Accident Analysis System, developed in 2000, with a more web-based system that uses GIS technologies within a crash analysis tool. Noting that replacing the existing system is more cost-effective than enhancing it, the agency expects to issue Requests for Information and Proposal, though it is unclear at this time if or when NCDOT will implement a new system.

Below is a brief state-by-state summary of the geospatial roadway inventory and traffic safety applications employed by the four states interviewed for this Preliminary Investigation that have not indicated an interest in significantly updating or replacing those systems and tools in the near future.

Arkansas State Highway and Transportation Department			
Type of Tool	**Tool Name**	**Development**	**Use**
Geospatial Roadway Inventory Tool	Virtual Integrated Safety User Assisted Location Tool	• Launched in 2011. • Developed in-house with minimal expense. • Uses the agency's existing LRS and GIS capabilities.	• Used by law enforcement with Google Earth to geospatially locate crashes and share data. • LRS includes roads on state highway system and other routes eligible for federal aid. • Currently requires manual entry of location but will be automated with 2014 implementation of eCrash (see What's Next below).
Traffic Safety Analysis Tool	I/Incident Analyst	• Began using in 2011. • Purchased three Intergraph licenses.	• Uses Intergraph's GeoMedia as GIS management platform to perform hot spot analysis and incident counts. • Replaces previous method of using GIS with CADD software to create crash analysis maps.
Related Issues			
System Support	Limited IT support needed; maintenance fees paid for vendor support of Intergraph products		
What's Next	• Expand LRS to include all public roads (now includes only state system roads). • Develop a dual carriageway system to identify two centerlines on divided highways. • Implement eCrash, a paperless crash reporting system that will automate entry of crash locations.		

Ohio Department of Transportation			
Type of Tool	**Tool Name**	**Development**	**Use**
Geospatial Roadway Inventory Tool	GIS Crash Analysis Tool (GCAT)	• Released in 2008. • Web-based tool.	• Not used for crash location in the field. • Includes spatially located crash data for both state and local crashes. • Requires users to set up a query form to isolate areas for crash analysis. • Displays crash data in geospatial format with the aid of ODOT's Base Transportation Referencing System, which ties relational databases to a geospatial location reference system.
Traffic Safety Analysis Tool	Crash Analysis Module (CAM)	Excel template built for GCAT to automate data analysis and queries	Users begin by exporting a GCAT query to CAM to view maps; create collision diagrams; calculate crash rates, severity rates and rates of return; and generate the ODOT Safety Application Score Sheet.
Related Issues			
System Support	Minimal maintenance since initial implementation		

Ohio Department of Transportation	
What's Next	• Convert to Esri's Roads and Highways for ODOT's road inventory to permit use of one official data set of road inventory data for each calendar year. • Update to GCAT to enhance display features. • Revamp the CAM tool within the next six months. • Create an in-car mapping tool for Ohio State Patrol that automates entry of some attributes of a crash report.

Texas Department of Transportation			
Type of Tool	**Tool Name**	**Development**	**Use**
Geospatial Roadway Inventory Tool	Geospatial Roadway Inventory Database (GRID)	• Began in 2011 with outside vendor. • Full deployment of LRS with GIS capabilities expected in late summer 2014.	• Includes web-based ad hoc query, analysis and reporting tools. • Uploads centerline map layers and roadway data files to CRIS (see below) to allow for crash analysis.
Traffic Safety Analysis Tool	Crash Records Information System (CRIS)	• Launched in 2007. • Developed under contract with outside vendor.	• Vendor enters crash data not supplied by online reports. • Interfaces with reporting system provided by MicroStrategy. • Expandable, with system facilities to aid in maintaining accurate data.
Related Issues			
System Support	• TxDOT elected not to migrate existing data from the mainframe system; instead, the agency populated system with five years of data entered by outside vendor. • CRIS project manager retained on contract, and consultants oversee reporting. Another vendor provides help desk support for online crash reporting system.		
What's Next	Public-facing crash data query slated for 2014 launch.		

Washington State Department of Transportation			
Type of Tool	**Tool Name**	**Development**	**Use**
Geospatial Roadway Inventory Tool	Incident Location Tool (ILT)	• Developed in three years. • Built as modular system using geoprocessing and cartographic services hosted on ArcGIS server.	• Once a location is selected, queries the agency's GIS and populates several data fields. • Geocodes and maps location elements.

Washington State Department of Transportation			
Type of Tool	**Tool Name**	**Development**	**Use**
Traffic Safety Analysis Tool	Collision Location Analysis System (CLAS)	• Developed in the early 2000s.	• Each week, uploads CLAS data to agency's Collision datamart to allow for analysis and reporting. • Spatially displays results sets from various ad hoc queries by integrating with WSDOT's GIS Workbench, a custom extension of ArcGIS for Desktop software. • After data are entered and fully processed in CLAS, uploads a data set to SafetyAnalyst for further analysis.
Related Issues			
System Support	• WSDOT maintains its LRS and GIS with state roadway data and has a license with MultiNet to obtain local road data. • Efforts are underway to partner with counties that have sophisticated GIS processing capabilities to create a statewide GIS layer with county roadway data. • A small team is responsible for CLAS maintenance and enhancement. The Oracle workflow team maintains the scanning and imaging workflow.		
What's Next	Integrate ILT with the online crash reporting system used by Washington law enforcement agencies.		

This Preliminary Investigation brought to light some common themes:

- More than one tool is used to geospatially locate and analyze crashes. The staff person leading MnDOT's project to replace its current traffic safety analysis system confirms this as a key finding from the agency's research to date.
- Some agencies (Florida, North Carolina and Washington State DOTs) are using their GIS environment to develop the tools needed to geospatially locate and analyze crashes.
- Local roadway data can be challenging to incorporate into an agency's LRS and GIS.
- Ad hoc and public requests for crash data are being addressed with tools or web access in development.
    - Florida DOT is developing a portal that will handle ad hoc requests for geospatial and tabular data for traffic safety analysis.
    - Texas DOT will launch a public-facing crash data query in 2014.
- Two agencies (Michigan and Washington State DOTs) are using SafetyAnalyst.
    - Florida DOT reported that its crash volumes were too high to be handled effectively within SafetyAnalyst.
- Many states are allowing electronic submission of crash reports to expedite data entry and sharing. States are also developing tools that law enforcement agencies can use in the field to spatially locate crashes, which can provide more complete and accurate data in crash reports.
- Enhancement to existing tools continues as users become more sophisticated and needs change.

Crash Location and Analysis Software

- Some of the commercial products we examined are used by the states highlighted in this Preliminary Investigation.
  - MicroStrategy's Business Intelligence Software provides the reporting utility employed by Texas DOT's traffic safety analysis tool.
  - The Crash Safety Analysis Tools Template from ArcGIS includes three standard crash analysis tools: sliding scale, spot and strip analyses.
  - Intergraph's GeoMedia is a GIS management platform that permits data aggregation from a variety of sources. Arkansas State Highway and Transportation Department uses GeoMedia in conjunction with Intergraph's I/Incident Analyst, which displays data in simple and complex maps. Mapping options include color-coded pin mapping, hot spot mapping and temporal reporting that produces incident/time-of-day histograms.
  - Esri's Roads and Highways spatially enables data from non-GIS systems and integrates it through the LRS.
- Tools supported by national associations include AASHTO's SafetyAnalyst.
  - Included in SafetyAnalyst is the Network Screening Tool used by Michigan DOT to conduct trunkline analyses.
  - Washington State DOT uses SafetyAnalyst to conduct some of the agency's crash analyses. We were unable to obtain detailed information about WSDOT's use of SafetyAnalyst at the time this report was published.
- Software developed in collaboration with university partners is used by local agencies.
  - Roadsoft, developed by Michigan Technological University and used by cities and counties in Michigan, combines a GIS-based interface with safety analysis tools.
  - Signal Four Analytics, in development at the University of Florida, is used by Florida government agencies responsible for law enforcement, traffic engineering and transportation planning, as well as by school boards and other Florida organizations to support their crash mapping and analysis needs.

Gaps in Findings

Four of the states consulted for this report—Florida, Michigan, Minnesota and North Carolina—are developing a new traffic safety analysis tool or report interest in doing so. While Minnesota's effort appears to be further along than the other states' inquiries, additional information from each of these states could be gathered in a follow-up investigation.

A follow-up investigation could also gather more targeted information about the tools of greatest interest to Caltrans to augment the high-level overviews provided in this report.

We were unable to learn more about WSDOT's use of SafetyAnalyst at the time this report was published. Contact information is provided on page 9 of this report should Caltrans wish to make this contact.

Next Steps

Caltrans might consider the following in its continuing evaluation of geospatial highway inventories and traffic safety analysis tools:

- Identifying the tool(s) of greatest interest to Caltrans and undertaking a more intensive information gathering effort specific to those tool(s).
- Consulting with agencies indicating an interest in replacing existing tools (Florida, Michigan, Minnesota and North Carolina) to learn more about their plans and what they have learned thus far.
- Investigating the use of an existing GIS framework to develop the tools needed to geospatially locate and analyze crashes by consulting with Florida, North Carolina and Washington State DOTs.
- Learning more about how Arkansas State Highway and Transportation Department leveraged existing LRS and GIS systems and processes to develop a low-cost crash location tool.
- Contacting the agencies that make guest access available for their traffic safety analysis tools (North Carolina and Ohio DOTs) to request such access. Texas DOT can be contacted to set up a site visit for demonstration of its tools.

Contacts

During the course of this Preliminary Investigation, we spoke to or corresponded with individuals from the following state DOTs or related agencies:

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State Practices

This section highlights eight state DOTs that are employing or investigating traffic safety analysis tools with a geospatial component. We conducted interviews with representatives from eight state DOTs—Arkansas, Florida, Michigan, Minnesota, North Carolina, Ohio, Texas and Washington—and provide a summary of those discussions and related resources in the following topic areas:

- Background.
- System description, functionality and use.
- Data analysis.
- Development and implementation.
- System maintenance.
- System access.
- What's next.
- Related resources.

A discussion summary may not include all of these topic areas. Some topic headings may vary slightly from those listed above.

Arkansas State Highway and Transportation Department: Virtual Crash Location Tool and I/Incident Analyst

Contact: Sharon Hawkins, Section Head, Mapping and Graphics, Arkansas State Highway and Transportation Department, 501-569-2205, sharon.hawkins@ahtd.ar.gov.

Background

Before the June 2011 launch of the virtual crash location tool dubbed the Virtual Integrated Safety User Assisted Location Tool, or VISUAL-T, locating and maintaining crash data in Arkansas involved the use of print or digitized maps on which law enforcement identified crash locations using county route, section and log mile. Using this practice to obtain accurate crash locations presented a variety of challenges.

In 2004, the Arkansas State Highway and Transportation Department (AHTD) began using a linear referencing system (LRS) to relocate crash location data. With LRS implementation, crash location data provided by law enforcement could now be verified digitally. However, most law enforcement officers lacked access to the LRS software. To create a crash location tool that could be easily used in the field, the agency used geographic information system (GIS) technology to place a virtual point every 100 feet along the road's LRS.

System Description, Functionality and Use

Each point in AHTD's crash location tool carries the key attributes of county, route, section and exact log mile. Each point was spatially intersected with the agency's roadway inventory data to reflect all roadway characteristics associated with the point (type of road, number of lanes, median type, etc.). City limits or jurisdiction boundaries can also be characterized to aid in accurately identifying crash locations.

With the LRS, AHTD can isolate a segment on the LRS and the system will visually represent where data is located on the federal aid system. The system will also display information such as job status (programmed or completed), year constructed, crash severity and mapped crash data. Each year a copy of the LRS is archived. This data layer can be used with the current LRS to identify areas where safety improvements have been made.

Points in the LRS are exported to a Keyhole Markup Language (KML) file to display in Google Earth at every 100 feet. AHTD crash locators and law enforcement officers in the field can click on a dot in Google Earth and get the necessary information to complete a crash report. The system uses color coding to identify the state highway system and other routes eligible for federal aid. The KML files can be shared by email, FTP site, Arkansas' GIS clearinghouse or ArcGIS online.

In the field, law enforcement personnel can use a smartphone to visually locate a crash in Google Earth using the street view function and click on that point to extract information identifying a crash location (route, section and log mile). Once an officer has identified the location using Google Earth, the location is manually entered into the crash report. Arkansas State Police's planned 2014 launch of a paperless crash reporting system—eCrash—will automatically enter log miles into the crash report, eliminating the current manual entry practice.

More than 40 Arkansas agencies have access to the crash location tool. Recent data indicates the tool has been used with approximately 50 percent of reported crashes in the state. AHTD crash locators no longer verify crash locations made using the crash location tool after quality control analyses indicated that almost all crash locations were being made correctly in the field when the crash location tool was employed.

Data Analysis

The crash location tool's utility is limited to geolocating crashes. In the spring of 2011, AHTD began using Intergraph's I/Incident Analyst to analyze crashes. Intergraph's GeoMedia is the agency's GIS management platform. Locations appearing on the crash location tool can be dynamically segmented on top of the LRS, and users can run analyses based on location.

The I/Incident Analyst Simple Hot Spot tool creates maps in GeoMedia, which show crash clusters much more quickly than previous methods. An analysis that had taken four hours using GIS with CADD software now takes just minutes with I/Incident Analyst.

Other features of the I/Incident Analyst system include:

- Incident Count, which counts the number of crashes within an area boundary.
- "Movies" that map crash data over time.
- Charts that summarize crash data.

The crash location tool reflects errors in the data, not as a visual representation on a map. It is possible to make modifications to a map generated in the crash location tool that will automatically generate the

appropriate changes to the relevant data in the database. The system uses live data at all times to permit this functionality.

Development and Implementation

AHTD used the LRS and GIS processes already in place to develop its crash location tool without the use of additional software. Development costs were minimal; the only significant cost was the purchase of Google Earth to provide map access to users in the field.

An implementation challenge specific to Arkansas is the limited Internet access in some rural areas of the state. In these locations, law enforcement officers in the field cannot connect to the crash location tool and Google Earth to locate crashes. When connectivity is a problem, officers must wait until returning to the office to identify the crash location, which had also been necessary prior to implementing the crash location tool.

System Maintenance

AHTD purchased three I/Incident Analyst user licenses for $5,000 and pays a continuing maintenance fee for product support. The agency pays an additional maintenance fee to use GeoMedia. No other significant IT support is needed to maintain the crash location tool. The agency maintains its roadway inventory and the LRS, and KML files reflecting the state system's roadway characteristics are updated every few months.

What's Next

- The agency expects to expand the LRS, which includes only state system roads, to include all public roads within the next five to seven years.
- AHTD is planning a dual carriageway system to identify two centerlines for divided highways, with the data set including complete data for log direction and anti-log direction.
- In 2014 the Arkansas State Police plans to launch eCrash, a paperless crash reporting system that automatically enters log miles into a crash report, eliminating the current practice of manual data entry by the officer at a crash location.

Related Resources

"Arkansas' Crash Location Tool: Recording and Analyzing Crash Information," Sharon Hawkins, Arkansas State Highway and Transportation Department, *GIS in Transportation*, May 30, 2013. (Click "OK" when presented with the FTP log-in screen.)
ftp://ftp.arkansashighways.com/outgoing/Intergraph/GIS-T%202013%20Presentation.pptx
This presentation provides an excellent overview of AHTD's crash location and analysis tools, with screen shots and commentary by Ms. Hawkins.

eCrash—Electronic Traffic Crash Reporting, Center for Advanced Public Safety, The University of Alabama, 2009.
http://caps.ua.edu/eCrash.aspx
This web site provides detailed information about eCrash, an electronic system for entering and processing traffic crash reports.

Florida DOT: Crash Analysis Reporting System

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Background

Florida DOT maintains the Crash Analysis Reporting (CAR) system to analyze crashes on state roadways. Developed in 1997 at a cost of $1.5 million, FDOT began using CAR to locate crashes in 2000 and for online crash analysis shortly thereafter. FDOT recently developed the Crash Location Analysis Reports (CLAR) system to analyze crashes occurring off the state highway system.

System Description, Functionality and Use

CAR is updated annually with information in Florida's long-form crash report. More than 300 variables classified in three categories (person, vehicle and crash) describe the site and time of the crash, geometric conditions, traffic control and characteristics of the driver and/or pedestrian. CAR data is processed using a centerline basemap of state roads; the system cannot geospatially locate crashes.

FDOT maintains a roadway inventory and LRS on all state-maintained roads. To create the Florida unified basemap, the agency is using a third-party basemap from NAVTEQ that reflects local roads together with the state-maintained roads already resident in the agency's LRS. With a long history of developing and using its LRS, FDOT is now moving to a GIS environment. That transition is not yet complete.

The agency is developing its own GIS tools for geospatial analysis of crash data resident in CAR using an enterprise Esri ArcGIS environment with a Silverlight ArcGIS server. Among the new FDOT applications developed within the agency's GIS framework is a hot spot analysis for pedestrian crashes that will be an add-in to ArcMap. Cluster and density crash analysis is also conducted using the agency's GIS tools.

Data Analysis

To make the best use of limited resources, FDOT is using the web-based access to the agency's enterprise ArcGIS environment to create tools that conduct hot spot analysis, locate crash clusters and determine crash density. FDOT's map-based geospatial analysis uses the ArcGIS framework to ensure access and consistency across the agency.

Two separate crash shapefiles are generated using an initial extract of CAR crash data. The coordinates for the crash locations within the CAR system use the LRS from FDOT's Roadway Characteristics Inventory. The first shapefile is for the crashes on the state highway system; the second is for crashes on public roads that are not part of the state system.

Shapefiles are shared with other agencies and organizations performing crash and/or safety analyses. Within FDOT, the shapefiles are used to perform geographic location-based queries and analyses using ArcMap. PDF and other image format files of maps can be created using the crash shapefiles as layers in ArcMap together with other ArcMap layers.

Annual reports are generated and ad hoc reports and analyses can be requested as needed. CAR produces annual analyses of crash rates and averages for both segments and intersections on the state highway system. CAR reporting categorizes roadways and intersections with crash data by:

- Average crash rate per type.
- Crash rate comparison.
- A rating for each segment on the state system.

Other analyses include segment-based sliding window analyses for locations of specific crash types and a crash rate analysis for a specific segment of roadway or corridor using system- and/or user-supplied parameters. CAR, and the analyses and reports it produces, is also used to select state safety projects.

Development and Implementation

The agency is balancing its LRS and crash reporting analysis with geospatial analysis. FDOT's enterprise environment simplifies development but requires conformance throughout the agency. Initial costs are reduced by employing the enterprise environment but can impact ongoing maintenance costs.

System Maintenance

Four full-time safety staff members and a team of part-time consultants maintain FDOT's crash location and reporting systems. FDOT's Office of Information Systems supports CAR. A full-time consultant maintains the agency's NAVTEQ-based products.

What's Next

After developing SafetyAnalyst and considering it for inclusion in the agency's suite of crash analysis tools, FDOT determined that its crash volume was too great for SafetyAnalyst to manage. As a result, FDOT will not purchase or maintain SafetyAnalyst.

To make crash data more available in the current environment, FDOT is developing a portal to handle ad hoc requests for geospatial and tabular requests for crash analysis.

The agency is planning to move from CAR, which is an LRS-based system, to a GIS-based tool that operates much like Signal Four Analytics (S4) (see **Other Florida Crash Analysis Tools** on page 14), a tool that FDOT currently doesn't use. The new tool would analyze all crashes statewide using a GIS basemap that provides spatial and attribute information compatible with FDOT's Roadway Characteristics Inventory database. Discussions are underway concerning sharing responsibility for a single system that serves the needs of both FDOT and local agencies. It is not known when such a tool will be developed and available for use.

Related Resources

Standardization of Crash Analysis in Florida, Albert Gan, Kirolos Haleem, Priyanka Alluri, Dibakar Saha, Florida Department of Transportation, March 2012.
http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_SF/FDOT_BDK80_977-10_rpt.pdf
This project was undertaken to identify existing crash analysis practices, problems and needs in Florida to help standardize the crash analysis methods and tools used throughout the state. The report includes an in-depth discussion of S4 as of the date of publication, including screen shots, as well as other crash analysis tools used in Florida.

NAVTEQ Maps, NAVTEQ, 2012.
http://www.navteq.com/
From the web site: NAVTEQ Maps provide the cornerstone to a new world of location experiences by enabling navigation, location-based services and mobile advertising around the globe. A product offering of Nokia's Location & Commerce business, NAVTEQ Maps and other valuable location content power automotive navigation systems, portable and wireless devices, Internet-based mapping applications and government and business solutions. By revolutionizing the way people think about and interact with maps, we foresee a world in which everyone finds their way to people, places and opportunities more easily and safely than before.

Unified Basemap Repository, Office of Information Systems, Florida Department of Transportation, undated.
https://www3.dot.state.fl.us/unifiedbasemaprepository/
From the web site: [The goal of this project is] to develop a standard, comprehensive transportation network that could be used throughout the State, shared across jurisdictional boundaries, through multi-agency involvement and coordination.

Other Florida Crash Analysis Tools

Contact: Ilir Bejleri, Associate Professor, Department of Urban and Regional Planning, University of Florida, 352-392-0997, ext. 432, ilir@ufl.edu.

Background

Signal Four Analytics (S4) is an interactive, web-based geospatial crash analysis tool funded by the state of Florida through its Traffic Records Coordinating Committee and under development by the University of Florida's GeoPlan Center. Development costs are estimated at $1.5 million.

The project began in 2006 to develop a web-based crash analysis tool for one of Florida's counties. After taking on a regional focus to serve the needs of central Florida, S4 development began to take a statewide focus. This web-based tool provides timely crash data, and requires little training and no special GIS software. Users include staff in Florida government agencies responsible for law enforcement, traffic engineering and transportation planning, as well as school boards and other Florida organizations.

System Description, Functionality and Use

S4 uses the NAVTEQ Florida unified basemap to provide interactive crash visualization on a cartographic or aerial photo basemap. Users can point and click on map points to locate crashes; query crash data by intersections, streets and corridors; and access scanned police reports and chart-based summary statistics.

Data Analysis

Crash data can be analyzed to generate:

- High crash segments and intersection by crash count.
- Crash rate.

- Crash severity.
- Collision diagrams.

Users can edit crash location and crash type, and export data, maps and charts. While averages are not yet being computed, the data is available to do so. S4 is expandable and can be enhanced to manage new analytical functions.

Development and Implementation

The project team's lead developer offers the following recommendations to agencies developing a crash analysis tool:

- Build a robust database.
- Provide lightweight, web-based tools that allow users to analyze data.
- Provide mapping capabilities with the use of a unified basemap.
- Make sure data can be made available for third-party analysis.

What's Next

In a pilot project, the S4 team is loading Florida Highway Patrol's 2011 and 2012 citation data to begin developing additional S4 analytical tools for law enforcement use. Future efforts will focus on enhanced analytics and network screening and development of a public interface with limited functionality.

Note: See page 32 for additional information about S4.

Michigan DOT: Safety Management System

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Background

A review of Michigan DOT's traffic safety analysis tools appears in the 2011 MnDOT report Minnesota Department of Transportation Traffic Safety Analysis Software State of the Art (see page 29 of the PDF available at http://www.dot.state.mn.us/research/TS/2011/2011-10.pdf). A recent discussion with Michigan DOT representatives indicates that little has changed in existing processes and functionality since the MDOT traffic safety analysis tools were examined for the 2011 report. Planning is underway to replace MDOT's primary traffic safety analysis tool.

System Description, Functionality and Use

MDOT's suite of traffic safety analysis tools includes:

- **Safety Management System (SMS).** Developed in 1993 and updated in 1996, SMS analyzes crash data by identifying high crash locations and permits site-specific investigations (for example, identifying problem intersections). The current system is a desktop tool and is not web-based, and does not provide a wealth of periodic reports. The roadway inventory data contained

in SMS dates back to 1996. Attempts to conduct mapping within SMS were unsuccessful. All crash analysis reporting associated with the agency's safety program and crash analysis conducted for other purposes is generated from SMS.

- **Roadsoft.** Used by local agencies (Michigan's counties and cities) and by MDOT staff assisting those agencies, this desktop tool offers users network analysis and mapping analysis capabilities, providing 10 years of functional crash data for analysis. Local users can modify engineering fields to change the local iteration of Roadsoft but those changes will not affect the statewide Roadsoft database. The MDOT LRS is part of Roadsoft and allows for mapping within the tool. Changes to a map within Roadsoft will generate a change in the underlying data.

- **SafetyAnalyst.** SafetyAnalyst is used for surveillance processes and to conduct trunkline roadway analysis using the Network Screening Tool. While SafetyAnalyst has the most up-to-date roadway inventory, no safety reporting is produced. All crash-related reporting is obtained through SMS.

The Michigan Geographic Framework provides statewide tabular and map-based data that combines Michigan's two LRSs to map coordinate-based systems. These interfaces allow the agency to perform mapping and tabular analyses using either coordinate- or LRS-based systems.

Data Analysis

SMS organizes safety analyses into road segment, intersection and interchanges. Systematic analysis of state roadways includes crash frequency, crash density and crash rates. Users can sort, filter, print and export crash data. Intersection crashes can be searched by road name, physical road number, control section and intersection ID. Other searches include:

- Control section from starting to ending mile points for road segments.
- Physical road number with starting and ending mile points for road segments.
- Mainline street and intersections for road segments.
- Data range for crash data for intersections and segments.
- Crash type areas for intersections and segments.

System Maintenance

MDOT has elected to limit future investment in SMS and does not provide IT support for Roadsoft.

What's Next

MDOT is planning to replace its SMS beginning in six months. It is not clear if development will be retained in-house.

Related Resources

"Michigan's Crash Data Analysis Tool for Local Agencies—RoadSoft GIS," Timothy Colling, Terance McNinch, Dale Lighthizer, Compendium of Technical Papers, *ITE 2008 Annual Meeting and Exhibit*, 2008.
Citation at http://trid.trb.org/view/2008/C/920646
From the abstract: This paper presents a case study of an initiative to provide local agencies in Michigan with the tools and resources needed to effectively conduct traffic safety analysis. Michigan has taken a

"teach them to fish" approach to dealing with crashes on local agency roads. That is: provide access to the data, provide access to the tools to efficiently analyze the data, and provide training and support on how to conduct the necessary analysis. Key to this initiative is RoadSoft GIS. Developed and supported by Michigan Tech University with funding support from the Michigan Department of Transportation, this system is available to Michigan's local agencies at no cost. Local agencies are provided powerful software pre-loaded with a GIS map of their road system and 10 years of historical crash data, as well as training and support. This system allows local road agencies to conduct sophisticated traffic safety analysis that they couldn't consider doing previously.

Minnesota DOT: Preparing for a New Traffic Safety Analysis Tool

Contact: Bradley Estochen, Office of Traffic, Safety, and Technology, Minnesota Department of Transportation, 651-234-7011, bradley.estochen@state.mn.us.

Background

The February 2011 research report Minnesota Department of Transportation Traffic Safety Analysis Software State of the Art examined traffic safety analysis tools used by other states to aid Minnesota DOT in its effort to replace its current crash analysis system. MnDOT's Transportation Information System (TIS), an integrated mainframe database with roadway and selected bridge, accident, traffic and pavement data, was developed more than 30 years ago and is used to determine where crashes are most common and the road improvements that could enhance safety. TIS does not employ the latest technologies in crash analysis such as roadway geometric data or additional data sources that can be used to more accurately locate crashes, identify crash trends and recommend appropriate countermeasures.

What's Next

MnDOT's review to date has netted valuable information. The results suggest that a suite of tools, rather than a single tool or vendor, is needed to leverage geospatial tools that identify and locate crashes along with a complementary statistical database that allows for crash analysis and networkwide reporting.

MnDOT's project to develop a new traffic safety analysis system is ongoing. The agency is reviewing information recently provided by four vendors in response to a request for information. This information will aid in preparing a Request for Proposal to develop the new system. MnDOT's goal is to have a new crash database implemented by January 2015, with crash analytics available later in the year.

Related Resources

Minnesota Department of Transportation Traffic Safety Analysis Software State of the Art, Minnesota Department of Transportation, February 2011.
http://www.dot.state.mn.us/research/TS/2011/2011-10.pdf
In this report, researchers identify and assess existing traffic safety analysis software tools currently used in other states and identify safety analysis capabilities that should be considered when replacing MnDOT's current traffic safety analysis tool. They gathered information through a web review and survey of state DOTs. Of the 22 states responding, researchers examined the web sites of four states—Maine, Michigan, South Carolina and Virginia—to better understand these states' experience with traffic safety analysis software. They also reviewed the traffic safety analysis tools of a fifth state—Maryland—in greater detail using Internet sources.

"Developing a State-of-the-Art Crash Analysis System," Minnesota Department of Transportation, June 2011.
http://www.dot.state.mn.us/research/TS/2011/201110TS.pdf
This technical brief summarizes MnDOT's research report Minnesota Department of Transportation Traffic Safety Analysis Software State of the Art. Page 2 of the PDF lists the functions researchers identified as important for a state-of-the-art crash analysis system to perform, including:

- Calculating crash metrics based on both severity and type.
- Identifying locations with potential safety issues using both black spot and systemic analyses.
- Conducting statistical analyses with comparisons between individual locations, networks and subsets of the network.
- Diagnosing crash issues, generating collision diagrams and identifying the distribution of crash types—such as rear-end, head-on and left-turn—and other crash attributes.
- Conducting an economic analysis estimating the cost-effectiveness of countermeasures, benefit-cost ratios and other metrics.
- Establishing a priority ranking of countermeasures based on location crash metrics and economic metrics.

North Carolina DOT: Traffic Engineering Accident Analysis System

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Background

Developed in 2000 by Keane Inc. in cooperation with North Carolina DOT, the Traffic Engineering Accident Analysis System (TEAAS) is a crash analysis software system freely available to state government personnel, municipalities, law enforcement agencies, planning organizations and research entities through download from the Internet. Initial development costs for TEAAS are estimated at $3.4 million.

TEAAS contains information about all reportable traffic crashes occurring in North Carolina since 1990, as well as ordinance information for all state-maintained roads and highways dating back to September 1955. A multitier, client/server-based system written in Java to ensure multiplatform compatibility, TEAAS is used by traffic engineering personnel and other agencies to perform crash analyses and review legal ordinances. The database contains crash, roadway, mileposting, crash code, ordinance and user information.

The North Carolina Division of Motor Vehicle's (DMV's) Traffic Records Communications System (TRCS) enables DMV to receive and process crash reports electronically, providing access to crash data within two to three weeks of submission. TRCS does not contain a mapping function that allows officers to spatially locate crashes when completing a crash report.

System Description, Functionality and Use

TEAAS uses mileposting to determine where crashes occurred, or where ordinances are located, in relation to roadway features. Mileposts are based on information in NCDOT's LRS. Features requiring

mileposts are intersections and interchanges, at-grade railroad crossings, mile markers, structures (that carry the road), and political boundaries (municipal, county and state lines). NCDOT's goal is to upload roadway data every quarter by importing snapshots using Oracle processes.

Users can create tables to import other data into TEAAS on an as-needed basis. For example, NCDOT has purchased travel time data from INRIX (see http://www.inrix.com/trafficinformation.asp) that can be stored in TEAAS and correlated with existing data. Pavement, budget, rail and other data can also be imported on an ad hoc basis.

TEAAS is not GIS-enabled. Hot spot crash mapping and spatial location are conducted outside TEAAS using Esri products. Data sets from TEAAS are imported to NCDOT's Spatial Data Viewer on an ad hoc basis to allow for mapping and analysis.

Data Analysis

PDF and Excel reports are available for the following areas of analysis:

- Severity.
- Frequency.
- Cluster/concentration.
- Crash rates.
- Critical crash rates.
- Sliding scale analysis (used to identify roadway segments with a high crash occurrence by varying the segment length; differs from a strip analysis program where an analysis segment is fixed).
- Collision diagram.

Ordinance information used in safety analyses (such as speed limits, no parking zones and signs on the roadway) resides in TEAAS, which permits its location on the LRS.

Users can identify patterns of problems with the mileposting process by reviewing data in TEAAS's tabular database. TEAAS includes strong processes to correct errors in crash data, but these errors are corrected in the data in a tabular format, not reflected spatially on a map.

Development and Implementation

Now Java-based, TEAAS previously used a mainframe process. A two-year project to migrate data included a backup plan that used an Access database to provide location data in the event the project team encountered implementation difficulties.

Under a continuing process to address system problems and incorporate enhancements, TEAAS has been enhanced to include ordinances, sliding scale analysis functionality, and improvements to reporting and processes.

System Maintenance

The unit overseeing TEAAS is dependent on IT resources for system maintenance and updates. A dedicated IT team supports the DMV's TRCS and TEAAS, with both units competing for state resources.

The Java-based desktop-client approach can generate user help requests that must be referred to IT. Having users outside the firewall creates risks for a desktop-based system, and a more web-based system is expected to reduce the user assistance now required.

System Access

TEAAS is freely available for download from the NCDOT web site (see https://connect.ncdot.gov/resources/safety/Pages/TEAAS-Crash-Data-System.aspx). NCDOT staff can provide a guest TEAAS account.

What's Next

NCDOT is investigating replacements for TEAAS. While not a critical need, solutions that are more web-based and employ GIS technologies within a crash analysis tool are being considered. According to NCDOT staff, implementing a new system with these features is more cost-effective than updating TEAAS to reflect them. The agency expects to issue Requests for Information and Proposal, though it is unclear if or when NCDOT will implement a new system.

Currently, 80,000 miles of the state highway system are entered in the LRS. As part of an upcoming enhancement, NCDOT will add 20,000 to 25,000 miles of city-maintained roads to the system.

NCDOT has planned another project that will combine the agency's LRS, GIS and roadway data with crash data using Esri's Roads and Highways software. Prototypes will be delivered this calendar year, with a proof of concept expected in the next few months. Implementation is targeted for fall 2014. The upfront functionality of TEAAS is not expected to change and maps will be generated as they are now (outside TEAAS), but the new system will provide more complete and current roadway data and will permit regular data uploads to TEAAS.

Related Resources

Traffic Engineering Accident Analysis System, North Carolina Department of Transportation, undated.
https://connect.ncdot.gov/resources/safety/Pages/TEAAS-Crash-Data-System.aspx
From the web site: The Traffic Engineering Accident Analysis System (TEAAS) is a crash analysis software system downloadable from the Internet and available at no cost to state government personnel, municipalities, law enforcement agencies, planning organizations and research entities.

Traffic Records Communications System, North Carolina Division of Motor Vehicles, undated.
https://dmvcrashweb.dot.state.nc.us/TRCS/
From the web site: NC TraCS is the North Carolina's implementation of the national model of the Traffic and Criminal Software (TraCS) package, originally created for the state of Iowa. The national TraCS model is used by 24 states in an effort to promote national standardization in the collection and processing of crash data. The NC DMV Traffic Records Communications System (TRCS) is an enhancement of the current Crash Reporting System that enables DMV to receive and process crash reports electronically.

Ohio DOT: GIS Crash Analysis Tool and Crash Analysis Module

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Background

Ohio DOT uses a suite of tools developed in-house to conduct crash analysis, including the GIS Crash Analysis Tool (GCAT) and Crash Analysis Module (CAM). ODOT's Base Transportation Referencing System, which ties relational databases to a geospatial location reference system, underlies GCAT to allow users to view crash data in a geospatial format. GCAT's mapping program uses a Bing application programming interface to produce spatially located data.

System Description, Functionality and Use

Released in 2008, GCAT is a GIS-based web tool that allows users to extract crash data spatially and create tables, charts, graphs and collision diagrams based on the crash data selected from the map. Officers at the scene create crash reports (paper or electronic), and the Department of Public Safety (DPS) enters these reports into a database. The data is uploaded weekly to an ODOT database and GIS warehouse, and made available for use by GCAT to map and analyze crashes. ODOT processes and analyzes crash data contained in the crash reports, spatially locating crashes and providing additional attributes in a format that is sent back to DPS to update its data repository.

GCAT includes both state and local system crash data that is spatially located using longitude and latitude. While the agency has the capability to upload crash data to ODOT's system within 24 hours, it typically takes approximately two weeks. Unlocated crashes, which are records where the latitude and longitude values are unknown and are reflected as zeroes in the database, are also included in the database. A 2012 GCAT update incorporated new crash report attributes and updated the system's query tools and data elements.

The Crash Analysis Module (CAM) is an Excel template built for GCAT to automate data analyses and queries, including crashes by day of the week; severity; and light, weather and road conditions.

Data Analysis

A query form derived from the crash reports uploaded to GCAT is segmented into when the crash occurred, crash details, driver/vehicle and location. Using selection tools, operators can isolate a map area for review or analysis by selecting a boundary layer, drawing a polygon to select corridors or intersections, or drawing a circle. Once the query form is created and the area of interest selected, GCAT updates and plots crashes on the map according to the query and area selected. Users can save custom shapes and queries for future use.

Individual crash records can be selected for review and scanned crash reports can be viewed. Access to the web-based, password-protected GCAT is made available to others outside ODOT, including local agencies, metropolitan planning organizations, county engineers and other public officials, and prequalified safety consultants. Users can also query and download crash data for their respective

counties from the 1.6 million crash records ODOT has made available. Errors are reflected in data, not on a map. Mapping changes cannot be made in real-time by the GCAT user.

CAM users begin with a GCAT query, copying their exported query to view maps; create collision diagrams; conduct a resurfacing analysis; calculate crash rates, severity rates and rates of return; and generate the ODOT Safety Application Score Sheet.

CAM is also used to create a "hand log" update file to update selected information about a crash, including crash type and the 14-character network linear feature identifier pinpointing the route on which the crash occurred. In addition, ODOT uses GCAT and CAM when reviewing district safety applications to select and fund projects for safety improvements. Similarly, metropolitan planning agencies use GCAT and CAM to create a safety priority list.

Development and Implementation

GCAT has been well-received by users. The simple yet robust tool offers an easy-to-use interface between the data and mapping capabilities. ODOT has found that when staff members gain a full understanding of the uses and benefits of the agency's crash analysis tools, they want more. Agencies launching such tools should be prepared to receive requests for enhancements and additional analysis and reporting options.

System Maintenance

Maintenance has been minimal since the tools were launched. Ongoing data maintenance includes managing unlocated crashes that show in the data. Errors in the road inventory are processed in another office and are reported by districts.

Crash data is updated quarterly through processes initiated by IT staff. A project expected to be completed in June 2014 will allow for weekly data updates.

System Access

Access to GCAT is available through the ODOT web site at https://gcat.dot.state.oh.us/SSL/Login.aspx; a guest login can be requested from ODOT staff.

The 2007-2010 version of CAM is available for download at http://www.dot.state.oh.us/Divisions/Planning/SPPM/SystemsPlanning/GCAT/CAM%20Tool%20Excel%202007-2010.xlsm.

What's Next

- ODOT will be using Esri Roads and Highways software for its road inventory within the next year. When the transition is complete, ODOT will use one official data set of road inventory data for each calendar year.
- A GCAT update is expected to include enhanced display features of other spatially located points, including a new data set of future projects.

- A project is underway to release to the Ohio State Patrol an in-car mapping tool that automates entry of 20 attributes of a crash report.
- A revamping of CAM is expected to begin in the next six to seven months to meet requirements under AASHTO's Highway Safety Manual. While the look and feel may change, the tool's purpose will not.

Related Resources

GCAT (GIS Crash Analysis Tool), Systems Planning and Program Management, Division of Planning, Ohio Department of Transportation, undated.
http://www.dot.state.oh.us/Divisions/Planning/SPPM/SystemsPlanning/Pages/GCAT.aspx
This web page includes links to GCAT tools and resources.

GCAT Training Classes Presentation, Ohio Department of Transportation, undated.
http://www.dot.state.oh.us/Divisions/Planning/SPPM/SystemsPlanning/GCAT/GCAT_Training_Classes_Presentation.pdf
This overview includes screen shots of GCAT and CAM systems.

Texas DOT: Crash Records Information System

Contact: Debra Vermillion, Director, Crash Data and Analysis Section, Traffic Operations Division, Texas Department of Transportation, 512-416-3137, debra.vermillion@txdot.gov.

Background

Texas DOT's Crash Records Information System (CRIS) is a PC-based application that contains spatial and reporting components that TxDOT staff use to obtain and analyze crash data. Funded with $9.9 million in state and federal funds, CRIS was implemented in the summer of 2006, with an outside vendor beginning the task of entering crash data for the previous five years plus the current year to meet Texas data retention requirements that went into effect in 2010.

In October 2007, responsibility for collecting and analyzing crash data as well as managing and maintaining CRIS, was transferred from the Texas Department of Public Safety to TxDOT. Shortly after that transfer, after a backlog of five years of data entry was complete, CRIS, with its more than 300 data fields, was available to TxDOT staff for crash analysis.

System Description, Functionality and Use

Centerline map layers and roadway data files are uploaded to CRIS from the Geospatial Roadway Inventory Database (GRID) system (see **Other Texas Geospatial Tools** on page 26). Data is collected for crashes on all Texas highways. Crash records are entered through three processes:

- Paper reports are manually entered into the system. The reports are scanned and turned into Tagged Image File Format images; a data entry vendor enters the data into CRIS. These reports are available for analysis within two days of submission. Approximately 47 percent of current crash reporting is submitted in paper.

- The Crash Reporting and Analysis for Safer Highways (CRASH) module of CRIS, a web-based interface used by Texas law enforcement agencies, allows for electronic submission of crash reports. Electronically submitted reports are available for analysis within four days of submission.
- XML Submission Services is a tool developed for Texas agencies with an existing crash reporting application, and requires a web services client and adherence to more than 800 business rules.

More than half of the crash reports received today are submitted electronically, either through the CRASH module or through XML submission. Ensuring that all reports are submitted and reflected in CRIS can be a challenge for the agency.

The system is expandable and has been subject to consistent upgrade and enhancement since its full implementation in late 2007. Recent updates include:

- The CRASH module of CRIS, which allows law enforcement officers in the field to submit crash reports electronically (2011).
- XML submission of electronic crash reports created in crash reporting systems other than CRIS (2012).
- A public-facing data query, similar to the crash data query conducted within CRIS but with only the data that may be made available to the public under Texas law (expected launch in 2014). Current practice is for the public to submit an online request and receive an email, typically within 14 business days, with the requested data.

System facilities aid in maintaining accurate data within CRIS, including:

- **CRASH correcting facility.** Relational edits are built in to validate crash reports entered by officers into the CRASH module. Neither the contractors entering the crash data in CRIS nor TxDOT staff members are permitted to alter data reflected on the crash report, but edits to the data within CRIS can be made when errors are identified. Map-related changes are made using the CRIS interactive locator (see below). Recent data indicates that 89 percent of crashes are located correctly.
- **Interactive locator.** A batch locate process reads the crash location identified by the officer in the field, locates the point on a map layer and generates the latitude/longitude coordinates. When errors are identified, changes to the map layer can be made to generate the appropriate changes in the underlying data.
- **Audit facility.** This process audits the work completed by the data entry contractor entering data from paper crash report submissions.

A vendor has been under contract since 2008 to enter crash data. Crash reports in CRIS from 2008 and 2009 reflect limited data fields. With the 2010 revision of the Texas crash report form, all data fields related to the crash report appear in CRIS.

Data Analysis

CRIS interfaces with a reporting system developed by MicroStrategy. The system initially produced 10 standard reports that mimicked the reporting available under the previous mainframe system. Mapping and other reporting can be generated using a search function. Most users request standard reports, though ad hoc reports that are customized to meet user needs can also be generated. Approximately 40 percent of CRIS users are classified as power users with the ability to create custom reports. Dashboard reporting is also completed for agency executive use.

Crash data within CRIS can be used to:

- Identify crash hot spots.
- Identify high-frequency crash locations, crash density by county or other defined area, and crash comparison by time of day.
- Complete cost-benefit analyses for all proposed safety projects in connection with the agency's Highway Safety Improvement Program using three years of crash data.
- Identify potential engineering fixes.
- Identify traffic operation needs.
- Inform public information and education campaigns.
- Serve as a political motivation tool.

Development and Implementation

CRIS was developed under a vendor contract. Data available from the mainframe system that predated CRIS was not migrated to the new system. Instead, TxDOT retained a data entry vendor to manually enter five years of crash data to populate the system for analysis. The data entry vendor continues to enter new paper crash reports into CRIS.

System Maintenance

While TxDOT recently outsourced its internal IT functions, contractors retained by TxDOT's Traffic Operations Division continue to oversee CRIS software maintenance. The state data center oversees the hardware used with CRIS software. The director of TxDOT's Crash Data and Analysis Section notes that the Traffic Operations Division's continued control of the vendor support for CRIS development and ongoing maintenance has contributed to the tool's success.

TxDOT maintains a CRIS project manager on contract and three MicroStrategy consultants to assist with CRIS reporting functions. TxDOT also retains a vendor to provide 24/7 help desk support for CRASH.

System Access

While CRIS is not available to users outside TxDOT, the system has been demonstrated for interested parties outside the agency through site visits. Interested agencies may contact Debra Vermillion for details.

What's Next

While the system is meeting current needs, continued enhancement of CRIS is expected, with a public-facing crash data query slated for launch in 2014.

Related Resources

C.R.A.S.H., Texas Department of Transportation, 2013.
http://crash-dev.tamu.edu/
From the web site: Crash Reporting and Analysis for Safer Highways (CRASH) is a secure website developed by TxDOT to allow law enforcement officers to submit the CR-3 crash report form electronically. The Crash Reporting and Analysis for Safer Highways (CRASH) system is a free, secure

Internet application for law enforcement agencies to process Texas Peace Officer's Crash Reports (CR-3) electronically. It is a component of the Crash Records Information System (CRIS).

CRASH and Submission Services Considerations, Texas Department of Transportation, August 14, 2012.
http://crash-dev.tamu.edu/wp-content/uploads/2013/02/Submission-Services-Considerations-9-14-12.docx
Directed toward law enforcement agencies, this document describes the considerations associated with electronic submission of crash data.

Data Management System Helps TxDOT Analyze Traffic Accidents, Adam Stone, Govtech.com, May 27, 2008.
http://www.govtech.com/public-safety/Data-Management-System-Helps-TxDOT-Analyze.html
This article, appearing on the Govtech.com online portal to the publication Government Technology, offers background about the development of CRIS, TxDOT's crash analysis tool.

Other Texas Geospatial Tools

Contact: Michael Chamberlain, Director, Data Management, Transportation Planning and Programming, Texas Department of Transportation, 512-486-5142, mchamb1@dot.state.tx.us.

Background

In the first development cycle of a multiphase project, Texas DOT sought to replace its legacy roadway inventory systems that are not in a geospatial format. The project team modernized the existing LRS to make a single LRS available to multiple applications. GRID, the new system, replaces multiple mainframe systems with a single geospatially based database environment that permits web editing and data entry. The project began in August 2011; full deployment of the LRS with GIS capabilities is expected in late summer 2014. Initial project costs are estimated at $2.2 million, with additional funding of $400,000 to $500,000 expected for enhancements.

Highlights of Phase 1 include:

- Enhanced quality control of GIS data entry.
- Web-based ad hoc query, analysis and reporting tools.
- Automated and integrated linear referencing method conversions.

System Use

The roadway inventory includes 150 attributes for roadways that are integrated with the roadway GIS layer. Data can be entered by staff or in a file format for a bulk load. Errors identified in inventory data that break the system's business rules are reflected in data form and spatially on a map. Users can access the cloud-based application through a browser with a TxDOT-provided login. Read-only access is available to a guest state DOT user upon request.

Development and Implementation

Data migration can be challenging and has been an ongoing issue for TxDOT (TxDOT was responsible for its own data migration). Recommendations for other agencies undertaking development of a geospatial roadway inventory include:

- Validate data before loading.
- Make sure your documentation is strong. Provide a graphical representation of what you expect the system to do. Break out functions and tasks and clearly identify them for developers.
- Create a dedicated team of testers.

The next phase of the project, slated to begin in late 2015, will modernize the editing, reviewing and reporting of data.

Washington State DOT: Incident Location Tool and Collision Location Analysis System

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Background

Washington State DOT's Incident Location Tool (ILT) is a map-based workflow enhancement system integrated with the agency's legacy collision data entry system, Collision Location Analysis System (CLAS). CLAS, a workflow tool that processes paper and electronic crash records, was built more than a decade ago as a collaborative effort between several state agencies and ImageSource. The code for CLAS was rewritten a year ago in DotNet.

ILT provides several geocoding tools, a measuring tool and map layers for visual reference. Once a location is selected, the ILT queries the GIS and populates several data fields. The agency's linear referencing system underlies the ILT, and the integrated crash analysis system will eventually interface with the Statewide Electronic Collision and Ticketing Online Records (SECTOR). In 2012, the agency estimated that 66 percent of collision reports in Washington were submitted electronically through SECTOR.

System Description, Functionality and Use

Staff members using CLAS and ILT are able to process the crash report from start to finish. Key functionality and benefits follow:

- Data entry time and overall processing time are reduced (report processing had taken 240 days; today's processing time is 58 days).
- Establishing location is faster and more accurate (30 seconds rather than 4 to 6 minutes).
- Fewer collision records are sent back to officers for corrections.

- A GIS application geocodes and maps all usable location elements.
    - The GIS application queries map layers and automatically populates several database fields (city, county, tribal reservation name, roadway name, milepost, and the name, direction and distance to the nearest cross street from where the collision occurred); other fields are still entered manually.
    - Final collision data records include all of the provided location information, including the latitude and longitude of the collision location, to allow collisions that occurred after 2010 to be geocoded to map-based software, such as ArcGIS.
- Statewide collision data is available for mapping and analysis.
- All of the server-side geospatial services, cartographic and geoprocessing, are available for other applications to use.
- The services-based architecture makes it easy to update geoprocessing and cartographic components with minimal disruption.

Mapping, or location coding, is done at the state, county and local road levels, and includes jurisdictional boundaries for tribes. The roadway feature inventory does not yet include such details as the length and type of guardrail or similar inventory items. Mapping errors are resolved by GIS unit staff, not by CLAS users.

Today, county crash reports are forwarded to counties to locate crashes. The county engineer locates the crash and enters data in ILT to expedite crash report processing. This special handling is necessary because counties employ different LRS methods than the states.

Data Analysis

CLAS data is uploaded weekly into the agency's Collision datamart to allow for analysis and reporting by WSDOT regions and divisions, other state government agencies, and public or private organizations. Data analysis includes:

- Identification of high crash locations by various criteria.
- Spatially displaying results sets from various ad hoc queries such as identifying collision hot spots by integrating with WSDOT's GIS Workbench, a custom extension of ArcGIS for Desktop software.
- Creation of collision diagrams for crashes identified by the analysis tools using either predefined or user-defined schematics.
- Drilling down to the actual crash report data in CLAS.

When data are entered and fully processed in CLAS, a data set is uploaded to SafetyAnalyst to permit further analysis. WSDOT can create maps and reports outside of CLAS using collateral systems such as WSDOT'S GIS Workbench, Collision datamart and SafetyAnalyst.

Development and Implementation

Developed to replace the less productive method of using online map resources to verify collision locations, ILT was under construction for three years and built as a modular system using geoprocessing and cartographic services hosted on an ArcGIS server. CLAS was developed in the early 2000s at a cost of $1.8 million. Plans are in place to integrate ILT with SECTOR, the online crash reporting system used by Washington law enforcement agencies. Development cost of SECTOR is estimated at $456,000.

Recommendations for other agencies considering implementation of traffic safety analysis tools include:

- Know your customer and design the tool to meet customer needs.
- Evaluate requests for enhancement to ensure that the need extends beyond a single instance.
- Ensure that the tool is working with clean data.
- Understand that working with spatial data may require a steeper learning curve than expected.
- Implement processes in phases.
- Recognize staff challenges with any system change. Some staff struggle with a culture shift that may occur when methods used to interpret and analyze data change.

System Maintenance

WSDOT maintains its LRS and GIS with state roadway data and has a license with MultiNet to obtain local road data. Efforts are underway to partner with counties using sophisticated GIS processing capabilities to create a statewide GIS layer with county roadway data.

A small team is responsible for CLAS maintenance, with 1.5 FTE responsible for maintaining and enhancing the system. Maintaining the scanning and imaging workflow is the responsibility of 0.5 FTE in the Oracle workflow team. Significant system enhancements to CLAS are managed within this team.

System Access

Proprietary information embedded in map layers limits the agency's ability to share access to its systems.

What's Next

Integrating ILT into SECTOR will include the following:

- ILT's interactive map, which will provide officers with all of the core map layers and tools.
- Integration with existing global positioning system receivers.
- Once a location has been identified, a simple map click in ILT will automatically populate several SECTOR data fields.

Related Resources

WSDOT's Linear Referencing System, Appendix A, Washington State Department of Transportation, undated.
http://www.wsdot.wa.gov/mapsdata/tools/traffictrends/tptappendicesforwsdotlrs.pdf
Pages 1 through 7 of the PDF provide a discussion of WSDOT's LRS.

"Incident Location Tool Getting Better Locations for Collisions," Warren Stanley, Paula Hammond, Steve Reinmuth, Washington State Department of Transportation, *2012 Tribal – State Transportation Conference*, October 2–3, 2012.
http://www.wsdot.wa.gov/NR/rdonlyres/646D96A5-55DF-48F3-8635-CD42B2A6BD0B/0/PlanningAheadToolstoBetterUnderstandourRoads_WarrenStanley_2012TribalConfIncidentLocationTool.pdf
This presentation includes some screen shots of the ILT and a good overview of the tool's functionality and uses.

Crash Location and Analysis Software

This section provides information about a limited selection of crash location and analysis software from commercial vendors and national associations, and tools developed in collaboration with university partners. Many of these tools are used by the states highlighted in this report.

Commercial Vendors

Business Intelligence Software: Government Solutions, MicroStrategy Enterprise Software Platforms, MicroStrategy Inc., 2013.
http://www.microstrategy.com/solutions/by-industry/government
This vendor provides the reporting utility employed by TxDOT's CRIS program.

Crash Safety Analysis Tools, ArcGIS, Esri, 2013.
http://www.arcgis.com/home/item.html?id=5537f21dc2d54d369fd14ea951648077
From the web site: The Crash Safety Analysis Tools Template for ArcGIS 10 is a set of custom ArcToolbox tools. Three industry standard crash analysis tools—sliding scale, spot, and strip are provided within the geoprocessing framework. The input datasets, analysis parameters, and output datasets can be modified to obtain the desired result. The outputs are high accident locations (HAL's) and selected crash records. These tools are useful for any safety analyst within a DOT.

GeoMedia, Intergraph Corporation, 2013.
http://geospatial.intergraph.com/products/GeoMedia/Details.aspx
From the web site: GeoMedia is a powerful, flexible GIS management platform that lets you aggregate data from a variety of sources and analyze them in unison to extract clear, actionable information. It provides simultaneous access to geospatial data in almost any form, uniting them in a single map view for efficient processing, analysis, presentation, and sharing. In addition, it has some specialized functionality that makes it ideal for anyone who needs to extract information from an array of ever-changing data to support smarter decisions.

> *Note*: AHTD uses GeoMedia as its GIS management platform.

I/Incident Analyst, Intergraph Corporation, 2013.
http://www.intergraph.com/landing/IncidentAnalysis.aspx
Used by AHTD to analyze its crashes, I/Incident Analyst can display data as simple and complex maps. Mapping options include:

- Pin mapping that generates color-coded pin maps based on database attributes such as incident date, time, location and offense type.
- Hot spot mapping that provides a number of commands for automatically extracting hot spots from a plot of incidents.
- Temporal reporting that allows users to create incident/time-of-day histograms.

Roads and Highways, Esri, undated.
http://www.esri.com/software/arcgis/extensions/roads-and-highways
From the web site: Esri Roads and Highways spatially enables business data from non-GIS systems and integrates it through the LRS. Roads and Highways, in concert with the ArcGIS platform, can be used to generate a variety of reports as well as produce data products and maps that support safety analysis, traffic congestion analysis, infrastructure maintenance planning, etc.

National Associations

SafetyAnalyst, AASHTO, undated.
http://www.safetyanalyst.org/
SafetyAnalyst is an AASHTOWare set of software tools used by state and local highway agencies for highway safety management. Michigan DOT uses the Network Screening Tool, which identifies sites with potential for safety improvement. The following description is from the FHWA web site:

> Network-screening algorithms are used to identify locations with potential for safety improvement, for example:
>
> - Sites with higher-than-expected crash frequencies, which may indicate the presence of safety concerns that are potentially correctable in a cost-effective manner.
> - Sites whose crash frequencies are not higher than expected, given the traffic volumes and other characteristics present at the site, but which nevertheless experience sufficient numbers of crashes that may potentially be improved in a cost-effective manner.
>
> In addition, the network screening tool can identify sites with high crash severities and with high proportions of specific crash or collision types. The network screening algorithms focus on identifying spot locations and short roadway segments with potential for safety improvement, but also include the capability to identify extended route segments. Network screening and all other SafetyAnalyst algorithms can consider specific crash severity levels (fatalities and serious injuries, fatalities and all injuries, property damage only) or all severity levels combined.

University Collaborations

Roadsoft, Center for Technology and Training, Michigan Technological University, undated.
http://www.roadsoft.org/
From the web site: Roadsoft's development began in 1992 based on input and guidance from local road agencies in Michigan. Over 400 road agencies and consultants use Roadsoft to manage their roads, signs, guardrails and other roadway assets. The software is maintained by a team of software engineers and civil engineers at the Center for Technology & Training (CTT) at Michigan Technological University.

Used by Michigan cities and counties, and by MDOT staff assisting local agencies, Roadsoft is a roadway management system that combines a database engine with GIS mapping tools. As part of the statewide roadway asset management initiative spearheaded and supported by MDOT, Roadsoft is available to local road agencies in Michigan at no cost. Roadsoft can be licensed for use by individual road agencies outside Michigan.

Related Resource

> **Integrated Roadway Asset Management System**, Center for Technology and Training, Michigan Tech Transportation Institute, April 2012.
> http://www.roadsoft.org/sites/roadsoft/files/RoadSoftMI_brochure.pdf
> This brochure describes Roadsoft's GIS-based interface and safety analysis tools. From page 7 of the PDF:
>
> - Detailed Safety Analysis tools enable you to analyze intersections, segments and curves, generate graphs to provide visual representations of trends, identify roads eligible for federal safety funding, and more.

- Network Diagnostics tools enable you to examine individual crashes to establish patterns and relationships, which can help identify areas where engineering changes could reduce the frequency and severity of crashes. Once you've identified problem areas, built-in links to NCHRP documentation can help you implement countermeasures.
- Integrated Crash Data allows you to visually compare crash data to roadway layers such as signs and signals. You can also overlay aerial photos and navigate through all levels of detail, including a public copy of the actual crash form.
- Powerful Reporting features include detailed standard crash reports and advanced filtering options, which allow unlimited reporting capabilities.
- Collision Diagrams provide visual representations of crash distributions at specific intersections. Collision diagrams also provide a means for measuring improvements, such as signal timing changes or additional signage.

Signal Four Analytics*,* Geo-Facilities Planning and Information Research Center, University of Florida, undated.
http://s4.geoplan.ufl.edu/
From the web site: Florida *Signal Four Analytics* is an interactive, web-based system designed to support the crash mapping and analysis needs of law enforcement, traffic engineering, transportation planning agencies, and research institutions in the state of Florida.

Florida Highway Patrol (FHP) is currently the statewide pilot agency for this system. The Geo-Facilities Planning and Information Research Center and FHP are working together to ensure that the system will fulfill law enforcement's crash analysis needs for identifying critical safety areas in order to apply enforcement and education countermeasures effectively to reduce fatalities and injuries on Florida's roadways.

Once the pilot phase is complete, Signal Four Analytics will be extended for use to interested traffic engineering, transportation planning and other law enforcement agencies in Florida.

> *Note:* See http://s4.geoplan.ufl.edu/?page_id=5 for a discussion of the tool's capabilities and screen shots.

Appendix A
State Practices in Managing Spatially Enabled Highway Inventory and Traffic Data

Background

The Preliminary Investigation to which this document is appended examined in detail the geolocation and traffic safety applications used by a select group of state DOTs. This appendix looks more closely at two elements that are also key to developing effective asset management and safety management programs—geospatially enabled highway inventory and traffic data. To gather this information, we conducted follow-up discussions with three state DOTs contributing information for the Preliminary Investigation.

Summary of Findings

Below is a summary of discussions with three agencies—Arkansas State Highway and Transportation Department (AHTD), and Ohio and Washington State DOTs—that sought to gather information about the systems, tools and practices used to spatially enable highway inventory and traffic-related data for asset management and traffic safety applications, and how those systems and tools are integrated. The discussion of state practices centered on three topic areas:

- Highway Inventory Applications.
- Traffic Data.
- Integrated/Interfaced Systems and Tools.

Highway Inventory Applications

While the roadway inventory data maintained by AHTD and Washington State DOT is not a complete dataset of state and local roads, Ohio DOT does maintain a complete dataset of all public roads. The limited roadway inventory dataset maintained by AHTD includes data for sample section routes on the local system that are required for submission to the Federal Highway Administration (FHWA) in connection with its Highway Performance Monitoring System (HPMS).

AHTD roadway inventory data is spatially enabled; the database housing Washington State DOT's roadway inventory data is not. Ohio DOT is undertaking an update of its roadway information management system that will provide the ability to query and display results as a report, graphically and geospatially.

The linear referencing systems (LRSs) maintained by Ohio and Washington State DOTs include both state and local roads; AHTD's LRS includes only those routes eligible for federal aid. All three agencies relate roadway inventory data to an LRS. Below we highlight other aspects of the agencies' use of highway inventory applications.

Arkansas

- Geographic information system (GIS) technology was used to place a virtual point every 100 feet along federal aid routes in AHTD's LRS.
    - Currently, the LRS includes only those routes eligible for federal aid. Expansion of the LRS to include all public roads is expected to be completed in the next five to seven years.
- Each point in the LRS is spatially intersected with AHTD's roadway inventory data so that all roadway characteristics are linked to each point in the LRS.
    - Among the challenges noted by the agency are discrepancies between the latitude/longitude coordinates resident in the LRS and drawn roadway coordinates.

Ohio

- Ohio DOT's Base Transportation Referencing System (BTRS) provides an official log of all highway latitude and longitude locations at every hundredth of a mile. The unique identifier in BTRS is also used for roadway inventory, traffic and crash data to consolidate multiple systems into a single LRS.
- Ohio DOT's roadway inventory is a complete dataset that includes both state and local roads, though some of the local data may not be current.
    - The agency is undertaking an effort to modernize its roadway information management system to address current challenges in maintaining data. The transition is expected to be complete at the end of 2015.
    - Transition to the new roadway inventory will include the importing of shape files from the Location Based Response System, a street centerline and point-based addressing system collaboratively maintained by state and county governments in Ohio.

Washington

- The agency's LRS uses data collected by Washington State DOT for state routes and local road data obtained through a license for TomTom's MultiNet.
    - TransMapper, an ArcGIS Explorer-based GIS application that is similar to Google Earth, is used to link roadway inventory data to the LRS.
    - GIS Workbench, an LRS-based, ArcGIS Desktop extension, is also used to link data to the LRS.
    - Three spatial LRSs include a Global Positioning System LRS, which is viewed as a more accurate method for locating and sharing data.
- Roadway inventory data for state routes is housed in the agency's Transportation Information and Planning Support (TRIPS) database, which also contains modules for crash analysis, traffic demand analysis, and a linear LRS. Roadway inventory data resident in TRIPS is not spatially enabled.

Traffic Data

All three agencies include annual average daily traffic (AADT) with roadway inventory data. While all three collect traffic data on state roads, traffic counts for local roads are limited to the data required for submission in connection with the HPMS. Washington State DOT provides a method for local agencies to

submit local traffic counts via the Internet. Below we highlight other aspects of the agencies' traffic data practices.

Arkansas

- AHTD processes both point counts and linear AADT counts, in which a series of traffic counts are generated from one point to another.
- Similar to its approach to gathering roadway inventory data, AHTD collects traffic data on all state roads and the traffic data required for submission for the HPMS for sample section routes on local roads.

Ohio

- Traffic data is collected on a three-year cycle for the state network. Local counts are limited and are based on HPMS requirements.
- All traffic data, regardless of the entity gathering it, is maintained on a single LRS.

Washington

- Traffic data in TRIPS is limited to state routes and is not spatially enabled.
- TRIPS feeds a traffic datamart with data that can be used for analyses in other applications, including the agency's GIS tools.

Integrated/Interfaced Systems and Tools

For AHTD and Ohio DOT, integration of systems and tools ties back to a single LRS that uses a common identifier to link data from multiple systems.

- The key to AHTD's system integration is having all information based on the same LRS, with the same key fields allowing for everything to be displayed spatially, and layering one dataset on another as needed.
- From a spatial perspective, data from Ohio DOT's various systems (traffic, safety and roadway inventory) is assigned the same identifier and is resident on the same LRS. Data is integrated from a corporate data warehouse that uses a BTRS roadway identification number to permit use within the agency's GIS applications and reporting across a range of applications.

Washington State DOT uses a variety of tools to support its asset management and traffic safety applications. Rather than taking a systemwide approach to integration, the agency's business needs drive integration of data and processes. TRIPS, the database that houses data on three systems critical to safety reporting (roadway inventory, traffic and crash data), is not spatially enabled, nor does TRIPS allow for easy integration of data among its modules. Internally developed GIS tools allow for data downloaded from TRIPS to be spatially displayed and analyzed.

Contacts

We spoke to the following individuals to gather information for this Appendix:

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State Practices

Below we highlight the systems, tools and practices used by three agencies that contributed to the Preliminary Investigation with regard to spatially enabling roadway inventory and traffic-related data for asset management and traffic safety applications. We conducted interviews with representatives from Arkansas State Highway and Transportation Department and Ohio and Washington State DOTs, and provide a summary of those discussions and related resources in three topic areas:

- Highway Inventory Applications.
- Traffic Data.
- Integrated/Interfaced Systems and Tools.

Arkansas State Highway and Transportation Department

Contact: Sharon Hawkins, Section Head, Mapping and Graphics, Arkansas State Highway and Transportation Department, 501-569-2205, sharon.hawkins@ahtd.ar.gov

Highway Inventory Applications

Arkansas State Highway and Transportation Department (AHTD) used geographic information system (GIS) technology to place a virtual point every 100 feet along each route in its linear referencing system (LRS). The agency expects to expand its LRS, which includes only roads eligible for federal aid, to include all public roads within the next five to seven years. A dual carriageway system is planned to allow for identifying two centerlines for divided highways, with the dataset including complete data for both log and anti-log directions.

Each point in the LRS, which contains county, route, section and exact log mile information, is spatially intersected with AHTD's roadway inventory data so that all roadway characteristics are linked to each point. With the LRS, AHTD can isolate a segment on the LRS and the system will visually represent where data is located on the federal aid system, also displaying information such as job status (programmed or completed), year constructed, crash severity and mapped crash data. Each year an archive copy of the LRS is saved. This data layer can be used with the current LRS to identify areas where safety improvements have been made.

Points in the LRS are exported to a Keyhole Markup Language (KML) file to display in Google Earth at every 100 feet. The system uses color coding to identify the state highway system and other routes eligible for federal aid. The KML files can be shared by email, FTP site, Arkansas' GIS clearinghouse, or through ArcGIS online.

The agency collects the roadway inventory data required for submission to the Highway Performance Monitoring System (HPMS), a national-level database of highway information that includes data on the extent, condition, performance, use and operating characteristics of the nation's highways. Data required for submission includes roadway inventory data on all state roadways and sample section routes on the local system. The agency uses a video log van that drives the state highway system to collect roadway inventory data; data is managed using Roadware Surveyor (see Related Resources below). The agency can locate assets by latitude and longitude in the video log, with a Global Positioning System (GPS) point identified every 5 meters. Google Street View is also used in connection with the roadway inventory.

The agency is responsible for maintaining its roadway inventory and LRS, and KML files reflecting the state system's roadway characteristics are updated every few months. Ms. Hawkins notes some challenges associated with maintaining roadway inventory data, including:

- Roadway inventory data is based on the agency's LRS, and sometimes the latitude/longitude coordinates resident in the LRS do not correspond with drawn roadway attributes. A latitude/longitude coordinate that falls within 50 feet of the centerline may be acceptable when working within a GIS environment or may require investigation to resolve.
- When working with spatial intersections in GIS, a buffer program can sometimes "grab" events that are part of another section. The user must be aware of this possibility and pay special attention to formulation of a query and its output.

Traffic Data

Annual average daily traffic (AADT) data is included in the agency's roadway inventory. The agency gathers both point counts, where the specific count location is known, and linear AADT counts, in which a series of traffic counts are generated from one point to another. While following the general practices used for roadway inventory data (gathering all HPMS-required traffic data for sample section routes on local roads and all state roadways), the agency's local road traffic data collection is done on a much larger scale than its collection of local roadway inventory data. Local road traffic counts are gathered with the cooperation of local agencies.

Integrated/Interfaced Systems and Tools

Using the spatial intersection tool that is native to all GIS programs, the agency can run queries in Intergraph's GeoMedia GIS platform using its crash, AADT and roadway inventory data. In addition to the segment-based linear crash analyses conducted using its GIS tools, the agency conducts point-specific crash analyses using Intergraph's I/Incident Analyst.

The interrelationship of the agency's systems and tools is described below.

- The agency's LRS, which is the basis for any data that will be mapped spatially, is based on the fields that make up the unique LRS identifiers: county, route, section, begin log mile and end log mile.
- The agency's roadway inventory data, which includes attributes such as number of lanes, average daily traffic, surface type, extra lanes, shoulder width and lane width, have the same key fields as the agency's LRS and is dynamically segmented on the LRS for spatial display. Job data (completed, under construction and programmed) also carries those key fields and is dynamically segmented for spatial display.
- Safety data (crashes) are located directly from the LRS data using the same key fields to allow for this data to be dynamically segmented for spatial display.
- Using the same key fields with all data based off the same LRS, everything can be shown spatially, and one dataset can be layered on another as needed.

Related Resources

Surveyor, Fugro Roadware Inc., undated.
http://www.roadware.com/related/down-loads/SURVEYOR_Version1.pdf
From the web site: Fugro Roadware's Surveyor asset extraction application, displays, measures, and inventories roadside assets located along the right-of-way (ROW). Using digital video obtained from a true HD Video Camera, Surveyor can locate roadside assets through the use of our proprietary technology which utilizes calibrated images and highly precise position information.

Ohio Department of Transportation

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Highway Inventory Applications

Geospatial Location Reference System

Ohio DOT's Base Transportation Referencing System (BTRS) is the result of the agency's effort to develop relational databases tied to a geospatial location reference system. Ohio DOT's January 2013 Roadway Information Manual provides this definition of the BTRS:

> BTRS provides an official log of all highway latitude and longitude locations at .001 mile and consolidates the department's various linear referencing systems using a 14-digit naming convention for each route in the State (see NLF_ID). The BTRS logpoints file is used to integrate various information systems for pavements, bridges, and safety as well as project development and road inventory. It allows data warehouses to combine data within and among the agency's various information systems.

The unique identifier in BTRS, assigned for every hundredth of a mile, is carried forth to apply a common identifier for other application systems (roadway inventory, traffic and crash data), thereby consolidating the different systems into a single LRS. Under the current system, as a point in the LRS moves—for example, to reflect a minor alignment adjustment—the underlying traffic and safety data moves with it. In other cases, such as realigning a road segment, the underlying traffic and safety data is lost. With the new roadway inventory that will be in place by the end of 2015, underlying information that may have been lost under the old system (due to significant changes in alignment, for example) will be retained as an historical reference for the former location.

Roadway Inventory

Ohio DOT collects and maintains an inventory of all public roads within the state. This inventory serves as the official record of the state, county and municipal roadways and includes over 121,000 centerline miles of roads and over 5 million entries of attribute data in 88 counties. From this, the agency has developed an official LRS, the BTRS. While the agency's roadway inventory is a complete dataset that includes both state and local roads, some of the local data may not be current. The agency maintains data for all state routes and relies on local partners to update information for local segments as it becomes available.

Modernization of the agency's roadway inventory system has been undertaken to address challenges associated with maintaining data. The agency will use one official dataset for roadway inventory when the transition to Esri's Roads and Highways is complete. With the new system, periodic, temporal releases of data will also be possible as new data is added. The two-year transition, expected to be complete at the end of 2015, will involve a move away from the agency's legacy dBase system.

A Scope of Services document (see Related Resources below) describes the tasks associated with transitioning to the new roadway inventory system. These tasks include:

- Migrating the roadway inventory database from its current dBase platform into an Oracle/Oracle Spatial database. Other associated Access files must also be migrated to Oracle.

- Developing data replacement and maintenance applications that will allow for a replacement of the editing tools in the existing dBase roadway inventory database with new editing tools within the new solution.
- Gathering the requirements for the visualization and reporting tools and applications to be developed.
- Developing a solution for transitioning from BTRS to a replacement solution. The department's LRS and associated roadway inventory datasets are currently tightly integrated with a number of systems throughout the agency. Changes to the base LRS and roadway inventory are currently perpetuated to these systems using BTRS.
- Conflating (overlaying and/or transferring attributes from) relevant roadway networks to the existing Ohio DOT centerline network, and replacing the Ohio DOT geometry with a county's geometry if that network is more accurate and/or detailed than Ohio DOT's existing network.

Other challenges associated with the agency's use of its current roadway inventory with other datasets include the future development of intersection tables. While Ohio DOT has gathered traffic volumes on all ramps and ramps are included in the state's roadway inventory, issues remain with regard to obtaining accurate crash reports from officers for crashes occurring on ramps.

Location Based Response System

The Location Based Response System (LBRS) is a current and accessible street centerline and point-based addressing system that is collaboratively maintained by state and county governments in Ohio. Seventy-seven of the state's 88 counties are participating in the LBRS program (75 counties have completed development and are providing LBRS-compliant data to the state). As the LBRS program sponsor, Ohio DOT provides technical guidance, support and data validation services.

One of the tasks in the transition to a new roadway inventory is to import LBRS county shape files into the new roadway inventory data model. The end goal of this task is to update Ohio DOT's roadway geometry, LRS and attributes to relate the improved information available through LBRS to the current roadway inventory attribute data files.

Traffic Data

AADT is maintained in Ohio DOT's roadway inventory. The agency is on a three-year cycle for collecting data on the state network. The traffic data collected includes a limited number of local counts in addition to counts on the state system. To submit the data required for submission to the HPMS, the agency has reached out to local partners to identify a random, though strategic, placement for traffic counts on local roadways. Using a traffic demand model, Ohio DOT staff then model traffic volumes using these randomly placed local counts to extrapolate volumes over the rest of the network to meet HPMS reporting requirements. All traffic data, regardless of the entity gathering it, is maintained on the same LRS.

Ohio DOT has identified all the required MIRE Fundamental Data Elements (FDE), though current roadway inventory data is limited for the local system. (The MIRE FDE have been established by FHWA and include segment, intersection and ramp data elements. The FDE were determined to be the basic set of data elements that an agency would need to conduct enhanced safety analyses to support a state's Highway Safety Improvement Program.)

Integrated/Interfaced Systems and Tools

From a spatial perspective, data from the agency's multiple systems (traffic, safety and roadway inventory) are assigned the same identifier and are resident on the same LRS. Ohio DOT's roadway inventory, traffic and crash data are integrated through a corporate data warehouse that permits use of the data in the agency's GIS applications and reporting across a range of applications. This data warehouse uses the BTRS roadway identification number and is segmented into records to represent every hundredth of a mile.

Another application that brings together multiple data sources for public use is the Transportation Information Mapping System (TIMS). TIMS is Ohio DOT's public web-mapping portal that provides access to roadway inventory, traffic volumes, construction project information and crash data (the latter is available through secure access). This platform provides a single access point for the public to view all such data spatially. See Related Resources below for a link to TIMS.

Related Resources

Comprehensive Transportation Asset Management: The Ohio Experience, Federal Highway Administration, 2007.
http://www.fhwa.dot.gov/asset/if07029/if07029.pdf
See page 10 of the PDF for a description of Ohio DOT's GIS-based Base Transportation Referencing System.

Related resource:

> **Appendix E: Glossary of Roadway Inventory Terms**, Roadway Information Manual, Ohio Department of Transportation, January 2013.
> http://www.dot.state.oh.us/Divisions/Planning/TechServ/Documents/Manual/Appendix_E.pdf
> See page 1 for the definition of Ohio DOT's Base Transportation Referencing System.

"Integrating Roadway, Traffic, and Crash Data: A Peer Exchange," *Transportation Research Circular*, No. E-C111, November 1-2, 2006.
http://onlinepubs.trb.org/onlinepubs/circulars/ec111.pdf
See page 65 of the PDF (page 57 of the report) for a discussion by a representative from Ohio DOT of the agency's integration of roadway, traffic and crash data. While this discussion is somewhat dated, the historical perspective and challenges noted are relevant to an examination of current practices.

Scope of Services, Roadway Information Management System, Office of Technical Services, Ohio Department of Transportation, undated.
ftp://ftp.dot.state.oh.us/pub/contracts/consult/Scope20130909/VAR-STWRoadwayInfo_Scope.pdf
This document describes the scope of services associated with the project to transition Ohio DOT's roadway inventory from its existing dBase system to a web-based solution. As the Introduction indicates, "[t]he project will allow ODOT to better satisfy newly identified requirements for the Highway Performance Monitoring System (HPMS) and the Moving Ahead for Progress in the 21st Century Act (MAP-21)."

Ohio's Location Based Response System, Ohio Geographically Referenced Information Program, Administrative Services Information Technology, State of Ohio, undated.
http://ogrip.oit.ohio.gov/ProjectsInitiatives/LBRS.aspx
The LBRS establishes partnerships between state and county government for the creation of spatially accurate street centerlines with address ranges and field-verified, site-specific address locations.

Related resource:

Ohio's Location Based Response System: How One Set of Highly Accurate, Shared Mapping Data is Saving Time, Money and Lives Across the Buckeye State, Ohio Department of Administrative Services, Ohio Office of Information Technology, White Paper, September 15, 2011.
http://gis3.oit.ohio.gov/LBRS/_downloads/docs/White%20Paper-LBRS_2011.pdf
Highlights from this White Paper describing the development of Ohio DOT's LBRS include:

- All data in the LBRS has to meet specific state standards for it to be accepted.
- Because it is field-verified, all LBRS data boasts positional accuracy to +/- 1 meter.
- The LBRS is updated regularly to ensure accuracy. Although the state only requires counties to update data annually, most are choosing to update more frequently.
- All information placed in the LBRS is in the public domain.
- Participation in the LBRS program is completely voluntary; more than 80 percent of the state's 88 counties have elected to participate.
- LBRS data is integrated into Ohio DOT's roadway inventory and is used as the official transportation map for the state of Ohio.

MIRE Fundamental Data Elements Cost-Benefit Estimation, Rebecca Fiedler, Kim Eccles, Nancy Lefler, Ana Fill, Elsa Chan, Federal Highway Administration Office of Safety, March 2013.
http://safety.fhwa.dot.gov/rsdp/downloads/mire_fde_%20cbe_finalrpt_032913.pdf
From the abstract: The Federal Highway Administration (FHWA) Office of Safety has established a fundamental set of roadway and traffic data elements that States should collect to support the activities conducted under their Highway Safety Improvement Programs. These data are a subset of the Model Inventory of Roadway Elements (MIRE), and are known as the MIRE Fundamental Data Elements (MIRE FDE). The objective of this effort was to conduct an economic analysis of the cost to States in developing a statewide linear referencing system and collecting the MIRE FDE on all public roadways.

Transportation Information Mapping System, Ohio Department of Transportation, undated.
http://tims.dot.state.oh.us/tims
Transportation Information Mapping System (TIMS) is Ohio DOT's web-mapping portal where users can discover information about Ohio's transportation system, create maps and share information. The system includes:

- **Road inventory.** Contains information regarding physical and administrative data related to the roadway network that are either maintained by or are of special interest to Ohio DOT.
- **Traffic counts.** Shows AADT and other traffic characteristics available by road segment for the state system (Interstates, U.S. highways and state routes) and selected local roadways. Traffic count station information is also available.
- **Safety data.** Contains information about crashes that can be located on all public roads in Ohio.

Washington State Department of Transportation

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Highway Inventory Applications

Linear Referencing Systems

Washington State DOT uses Esri's ArcGIS software in conjunction with state roadway inventory data and three spatial LRSs: 500k, 24k and GPS LRS. Data is collected every hundredth of a mile. The three spatial LRSs are accessed through the agency's GIS Workbench, an internally developed GIS tool. The 500k LRS depicts state routes with one line representing a highway's geographic location; the 24k LRS depicts undivided state routes with one line and divided routes with two lines. Locations for the GPS LRS, which represents all state routes in Washington depicted by two lines, were collected using a moving vehicle outfitted with GPS technology. The GPS LRS has a horizontal accuracy of +/- 5 feet and is seen as a more accurate method of locating and sharing data.

WSDOT has a license for TomTom's MultiNet to obtain local road data for its LRS. The local road data that is purchased to help manage the LRS is not updated as frequently as the agency would wish. Problems with data correspondence can occur when WSDOT geospatially aligns the purchased data with the state route data it collects. Efforts are underway to partner with counties with sophisticated GIS processing capabilities to create a statewide GIS layer to include county roadway data, which would eliminate the need for purchased data.

Roadway Inventory Data

Roadway inventory data for state routes is collected and updated using contract plans, field reviews and information provided by numerous WSDOT regional and headquarters offices, as well as other county and city sources, over the course of a year.

Roadway inventory data for state routes is housed in WSDOT's Transportation Information and Planning Support (TRIPS) system, a mainframe, data-based, integrated system that includes four modules: roadway inventory, LRS, crash analysis and traffic demand analysis. Roadway inventory data maintained in TRIPS includes data on number of lanes, special lane types, total roadway width, medians, (paved) shoulders and ramps. Manual processes have been developed to use the TRIPS data, which is not spatially enabled, in WSDOT's GIS applications.

Other Tools

TransMapper, short for Transportation Mapper, is an ArcGIS Explorer-based, lightweight GIS application that is similar to Google Earth and is used to link data to the LRS. TransMapper provides complete orthophoto and road coverage of the state, and allows for simplified custom mapping.

GIS Workbench is an LRS-based, ArcGIS Desktop extension that provides WSDOT with custom tools and simplified data access methods for connecting to the agency's enterprise GIS databases. The Workbench makes it easier for users to link data to the LRS, and provides easy access to hundreds of GIS layers that can be used for analysis or display. Use of the Workbench ensures that the most current data is available across the agency, and the custom spatial tools offer users flexibility in mapping and locating projects.

Traffic Data

Traffic data is a feature of the agency's roadway inventory. The TRIPS system, developed in part to meet HPMS submission guidelines, is WSDOT's database for storing state route traffic data. TRIPS feeds the WSDOT traffic datamart with data that can be used for analysis.

Local traffic data is not resident in TRIPS. Instead, local agencies are provided with a web interface to enter the local traffic data needed for HPMS reporting. The sections to be reported are specific roadway segments that are classified as Principal Arterial, National Highway System or HPMS sample segments. See the "HPMS Data Collection" entry in Related Resources below for the web site used by local agencies to enter traffic data, including a description of the data collected.

Integrated/Interfaced Systems and Tools

Data downloaded from TRIPS to three datamarts—collision, roadway and traffic—provide datasets for use with GIS and allow users to generate other reporting and analysis that is not available within TRIPS. Unlike the roadway and traffic datamarts, the collision datamart includes data for on- and off-system roads. Use of the datamarts for data analysis has raised concerns about the currency of the data when data in the datamart is out of sync with data in TRIPS. And while the TRIPS database houses data on three systems critical to safety reporting, the WSDOT contacts note that the TRIPS database is not very flexible, and it can be challenging to gather and manipulate the data. A 2009 WSDOT study examined the feasibility of replacing TRIPS (see Related Resources below).

At this time, there is no statewide plan for state and local agencies within the state to work together to develop a comprehensive basemap using a single source of data. Some counties are ahead of the state in developing GIS layers, and the state is playing catch-up. Integration within the agency is driven by business needs; there is no system-driven integration of applications and tools. The WSDOT contacts note that support from the highest levels of an agency and adequate funding are necessary to ensure system integration and effective use of asset management and traffic safety applications.

Related Resources

Transportation Asset Management Feasibility Study, Washington State Department of Transportation, June 2009.
http://www.wsdot.wa.gov/NR/rdonlyres/6D9A5214-AEC5-4298-923F-8E9D644A720D/0/WSDOTTransportationAssetManagementFeasiblityStudyFINAL.pdf
This study that considers replacement of TRIPS provides a summary of the four TRIPS modules on page 27 of the PDF. See page 7 of the PDF for a summary of the problems with existing business processes, including the use of TRIPS, as noted by stakeholders.

HPMS Data Collection, Washington State Department of Transportation, undated.
http://www.wsdot.wa.gov/mapsdata/travel/hpms/
From the web site: The HPMS Web Application is used to gather and update information for HPMS Roadway Sections. These sections are specific roadway segments that are Principal Arterial, National Highway System (NHS), or HPMS Sample segments. The web application input form has edit checks, a search capability and the option of printing or saving your input.

Market Research for Idaho Transportation Department Linear Referencing System (LRS), Idaho Transportation Department, September 2, 2009.
http://itd.idaho.gov/highways/research/archived/reports/RP198%20-%20Final%20LRS%20Report%20with%20ITD%20Cover.pdf
See page 33 of the PDF for discussion of WSDOT's LRS. This document describes the two systems WSDOT has developed: a distance measuring instrument (DMI) LRS on all state highways, and a spatial LRS that is used for spatial reference in a GIS. The DMI LRS was created by driving state highways with a vehicle-mounted, high-accuracy odometer. Researchers note that three spatial LRSs have been developed over time to increase the horizontal accuracy and level of detail: the 500k, the 24k, and the recently completed GPS LRS.

Geographic Services, Washington State Department of Transportation, January 2009.
http://www.wsdot.wa.gov/NR/rdonlyres/EEDA44F7-3B51-4FF3-84E1-5830C705EAC7/0/GeographicServicesFolioJanuary2009.pdf
This publication provides information about the products and services provided by the agency's Cartography and GIS Branch, including TransMapper and GIS Workbench.

WSDOT GeoData Distribution Catalog, Washington State Department of Transportation, 2010.
http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm#links
The GeoData Distribution Catalog makes a wide range of GIS data available to the public.