APPENDIX A

Summary of Published State DOT Case Studies

Table A1 summarizes the status of roadway safety data integration efforts published as state DOT case studies. The efforts of each state is presented in four categories: 1) Data Collection Efforts, 2) Data Integration, Maintenance and Management Efforts, 3) Impacts of Data Integration, and 4) Challenges and Lessons Learned. The first category, Data Collection Efforts, details any of the state's collection practices and who is responsible for carrying out those practices. Next, the Data Integration, Maintenance and Management Efforts explains what tools the state has used to consolidate, combine, or manage its data collections. The Impacts of Data Integration illustrates the results of the previous integration and maintenance practices, highlighting what processes have been made easier and more efficient. Finally, in the Challenges and Lessons Learned section, the agencies noted which items were difficult to accomplish during the data collection, integration, and maintenance efforts and offer advice for other agencies to follow.

It should be noted that the information provided in Table A1 reflects the state-of-the-practice at the time this synthesis report was written.

TABLE A1
SUMMARY OF STATE DOT CASE STUDIES ON INTEGRATION OF ROADWAY SAFETY DATA

STATE	PHASE	DESCRIPTION
Alabama	Data Collection Efforts	ALDOT Enterprise GIS (EGIS) is comprised of a Linear Referencing System for all the roads in the state of Alabama and its associated data attributes (FHWA HSIP Report 2015, https://safety.fhwa.dot.gov/hsip/reports/pdf/2015/).
	Data Integration, Maintenance and Management	The Alabama Department of Transportation (ALDOT) led the effort to develop ALSAFE, a spreadsheet-based safety tool that can be used for short- and long-range transportation safety planning. ALDOT developed ALSAFE to serve as a safety planning tool for MPOs (FHWA-SA-17-015).
Alaska	Data Collection Efforts	The Transportation GIS unit is responsible for roadway and asset data. The crash data manager is responsible for crash data and traffic volume data. The Design and Engineering Services divisions also collect asset data while the Maintenance Management System collects the maintenance data. Alaska is currently working on putting a safety-related data collection plan (TRB Circular E-C196).
	Data Integration, Maintenance and Management	Crash data management is currently formalizing QA/QC into Version 2 data entry. Data analysis is carried out using LRTP, SHSP, HSIP, and CRASH to identify policies, planning, and research needs for safety (Thompson *FHWA Safety Compass Newsletter* 2016). Alaska's most successful safety data integration effort has been the comprehensive Spatially Integrated Roadway Information System (SIRIS), which combines the RDS and crash systems (TRB Circular E-C196). Roadway, traffic, and crash data are linked. Crash data are not linked to other databases (injury, citation, road weather, etc.). The *Alaska Preconstruction Manual*, however, integrates crash records with other data. The Crash Data Repository (CDR) is used for analysis and mapping of safety data workflows. Its linear referencing system covers roadway data, crash data, traffic data, asset data, and maintenance data. Alaska makes use of ArcGIS online, LiDAR, Esri Maps for Office, Intersection Magic, and named intersections, segments, and corridor analysis for data access and visualization (TRB Circular E-C196).

STATE	PHASE	DESCRIPTION
	Challenges and Lessons Learned	Challenges for Alaska's data integration include: CDR full implementation for electronic data transfer from DMV to DOT, integration of health and crash records at state level, and Transportation Asset Management Information System (TAMIS) implementation lacking a leader (TRB Circular E-C196).
Arizona	Data Integration, Maintenance and Management	ADOT recently finished a pilot project in conjunction with the Federal Highway Administration (FHWA) that makes local and Tribal agency data available to the state in the Arizona Transportation Information System (ATIS) database. Arizona received data from the Bureau of Indian Affairs (BIA), the Maricopa Association of Governments (MAG), the Navajo Division of Transportation, and the Pima Association of Governments (PAG). Local and state data were combined and then exported, transformed, and loaded (ETL) into AASHTOWare Safety Analyst^{TM} (FHWA-SA-16-061).
	Impacts of Data Integration	The integrated data set allows roadways, traffic volumes, and accident records to be imported into the same system. ADOT created guidelines on how future data can be imported and assessed when it is collected. It was reported that the guidelines have improved data loading and made it more user-friendly. It also helps pinpoint errors or outliers in the data. The ETL process launched by this pilot project can now help ADOT move further in analyzing intersections and more intricate variables (FHWA-SA-16-061).
	Challenges and Lessons Learned	The Arizona DOT State and Local Safety Data Integration pilot project pulled data from the ATIS and Safety Data Mart (SDM) databases, then integrated it into a uniform format to be processed by AASHTOWare Safety Analyst^{TM}. In order to do so, the project team had to resolve the varying forms of data and code from ATIS and SDM, converting the files into .csv format and enabling data to be moved from source to proper database (FHWA-SA-16-118).
Arkansas	Data Integration, Maintenance and Management	MIRE is connected with the eCrash, which will improve the data quality for analysis. MIRE roadway data elements are the priority for improvements in HSIP (FHWA HSIP Report 2015, https://safety.fhwa.dot.gov/hsip/reports/pdf/2015/).
Colorado	Data Integration, Maintenance and Management	Using GIS to pool roadway data and crash data together. This visual data enables them to develop safety performance functions (SPF) and determine Level of Service of Safety (LOSS). These analysis tools can be used to drive countermeasures with the budget in mind (FHWA Safety Compass Newsletter 2017).
Georgia	Data Integration, Maintenance and Management	Crash location is all geo-coded (FHWA HSIP Report 2015, https://safety.fhwa.dot.gov/hsip/reports/pdf/2015/).
Idaho	Data Collection Efforts	Idaho Transportation Department (ITD) Division of Engineering Services collects roadway data, asset data, and maintenance data. The Office of Highway Safety collects crash data, traffic volume data, and major corridor incident data. ITD is currently developing a safety-related data collection plan that uses planning and prioritization tools (TRB Circular E-C196).
	Data Integration, Maintenance and Management	The data systems are not currently linked. ITD is working on establishing a data warehouse comprising of all data systems. The Office of Highway Safety has established a set of database business rules, and it maintains a crash data dictionary. Aside from crash data, other data systems do not have a management plan currently in place. Office of Highway Safety also oversees the SHSP safety analysis and other data evaluation components. The Highway Performance Monitoring System (HPMS) and LRS are used for roadway data, but they largely only include state roads. ITD is working on making this technology compatible with ARNOLD (TRB Circular E-C196).
	Challenges and Lessons Learned	Idaho's most successful safety data integration effort has been its roadway data and crash records. Challenges for Idaho's data integration include project scoping and preconstruction. Work has yet to be done on them (TRB Circular E-C196).

<table>
<tr><th>STATE</th><th>PHASE</th><th>DESCRIPTION</th></tr>
<tr><td>Illinois</td><td>Data Integration, Maintenance and Management</td><td>The Illinois Department of Transportation (IDOT) has implemented an enterprise data governance approach for managing data collection, storage, distribution, and use throughout the organization. The Illinois Traffic Records Coordinating Committee (ITRCC) directs the IDOT safety analysis activities, which includes identifying severe crash locations and segments, prioritizing locations for treatment, and performing systemic safety analyses (FHWA-SA-16-108). In 2013, IDOT embarked on a pilot program for nine counties in the use of United States Road Assessment Program (usRAP) for county routes.

A depiction of the information flow for an enterprise database can be found below in Figure A1. This type of flow was established in order to avoid data duplication, but is recommended with systematic management (DeLucia et al. 2012).

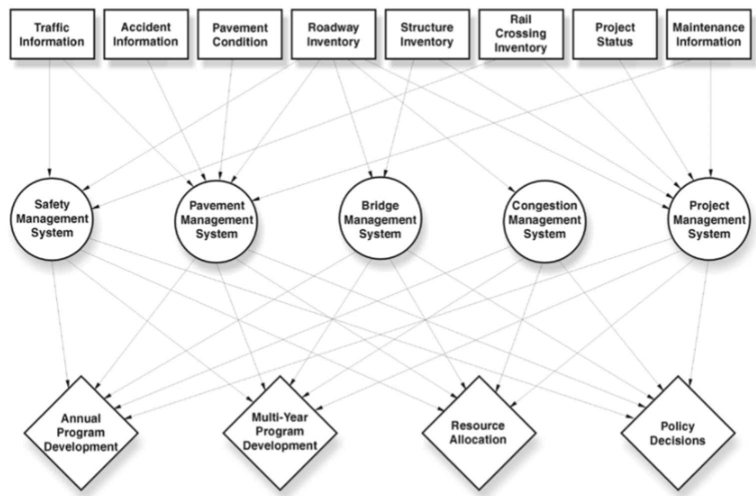

FIGURE A1 Illinois DOT information flow for asset management (DeLucia et al. 2012)</td></tr>
<tr><td>Indiana</td><td>Data Integration, Maintenance and Management</td><td>In the Indiana Local Technical Assistance Program pilot project, GIS-based data integration and analysis were introduced to the Indiana Local Technical Assistance Program (LTAP) to support communication for future projects. This approach was broken down into four phases: GIS assessment, GIS data development and integration, GIS website development, and asset data collection. Creating a central, user-friendly, and map based information system, providing technical support, and governing data extraction/implementation were among the goals of this pilot project (FHWA-SA-16-118).</td></tr>
<tr><td>Iowa</td><td>Data Collection Efforts</td><td>The Research and Analytics division at Iowa DOT collects roadway data, while the Office of Motor Vehicles collects crash data. The Systems Planning unit collects traffic volume data and the Maintenance division collects maintenance data. The Traffic Operations unit collects major corridor incident data. Iowa DOT has not yet formalized an effort to implement a safety-related data collection plan (TRB Circular E-C196).</td></tr>
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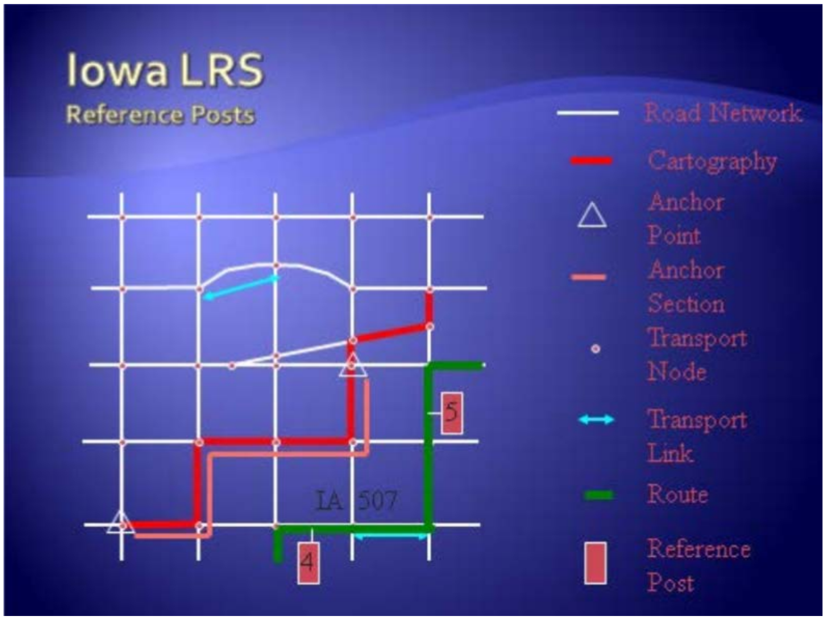
STATE	PHASE	DESCRIPTION
	Data Integration, Maintenance and Management	The Office of Traffic and Safety at the Iowa DOT is responsible for SHSP safety analysis, network screening, predictive analysis, and other data evaluation components. Safety data workflows are not currently mapped or documented. There is a common LRS available for roadway, traffic, crash, asset, and maintenance data, and these are compatible with All Road Network of Linear-Reference Data (ARNOLD). Safety data management plans were reported to be underway but incomplete. Iowa DOT uses the Intersection Magic (collision diagrams), ArcGIS, and a Crash Mapping Analysis Tool (TRB Circular E-C196). A cross-referencing system is used to analyze the effects of improvements and countermeasures. It is accessible to engineers, emergency workers, government officials, and even non-transportation agencies. This database can support numerous components of roadways and large amounts of data, but the system must be maintained properly (DeLucia et al. 2012). An illustration of this system can be found below in Figure A2.  FIGURE A2 Iowa DOT example of using multiple location methods (DeLucia et al. 2012)
	Impacts of Data Integration	With the real time GIS updates, there is no need for redundant record keeping, the cost of employing plows/drivers is reduced, and the public is kept up to date during inclement weather (FHWA Safety Compass Newsletter 2017).
	Challenges and Lessons Learned	Iowa's most successful safety data integration effort has been its GIS portal, which includes roadway and crash data information. Challenges for Iowa's data integration include any initiatives dealing with personal and private information (TRB Circular E-C196).
Kentucky	Data Collection Efforts	State DOTs often neglect county secondary roads or any roads not maintained by state transportation agencies, and it is these inadequately designed roads where the worst of accidents tend to occur. In Kentucky, this was the case for half of the 80,000 miles of public roads. As a result, the Kentucky Transportation Center (KTC) collected data from 10 pilot counties and small cities and processed that data via usRAP tools. usRAP then provided possible remedies for design deficiencies, and it demonstrated the noticeable payoff of usefulness per effort (FHWA-SA-16-028).

STATE	PHASE	DESCRIPTION
Louisiana	Data Collection Efforts	Louisiana Department of Transportation and Development (LADOTD) has paid a private consultant $20 million over the course of six years for asset data collection and processing (FHWA-SA-13-007).
	Data Integration, Maintenance and Management	LADOTD is currently investing time and efforts in maintaining asset data in order to carry out safety analyses and make sure it is up to date. They have added a position opening for an asset management engineer and have already hired an asset manager with IT experience. As of now, they rely on consultants and local agencies to update data (FHWA-SA-13-007).
	Challenges and Lessons Learned	Multi-disciplinary Road Safety Assessment (RSA) teams working together make low cost safety improvements possible. They need to coordinate their efforts. LADOTD suggests other state agencies should first contact their local agencies and use data that already exists as a starting point. The next step is to plan data collection for the remaining information. One challenge for the local roadway asset data is keeping roadway information up to date. In order to help meet this challenge LADOTD is working to compile an online map that local agencies can access and update their local roadways (FHWA-SA-13-007).
Maryland	Data Collection Efforts	The Office of Planning as well as the Data Services Engineering Division collect roadway data, asset data, and traffic volume data. The Office of Traffic and Safety collects crash data. The Office of Maintenance collects maintenance data. The Coordinated Highway Action Response Team (CHART) collects major incident data. Several different groups oversee the individual components of the asset data (TRB Circular E-C196).
	Data Integration, Maintenance and Management	Maryland's numerous state agencies send their data through the University of Maryland's National Study Center for Trauma and Emergency Medical Services (NSC), where it is evaluated via Crash Outcome Data Evaluation System (CODES). This procedure attempts to output a quantitative, statistical correlation among crash, vehicle, and driver behavior to their respective degrees of severity, both injury and money wise. Implemented in 1992 by the National Highway Traffic Safety Administration (NHTSA), the CODES program is still in use today thanks to the NSC's own funding after the NHTSA stopped funding the program in 2013. The three core data sets used by the NSC are crash, emergency medical services, and hospital. These sets are supplemented by driver licensing, vehicle registration, driver record, trauma registry, and other available data. This program includes all public roads in Maryland and is aided by over two dozen collaborative agencies across the state. Annual data submitted to the NSC is compatible with a General Use Model (GUM). Those data submissions follow other NHTSA data systems and are also collected by most states (FHWA-SA-16-049).
	Challenges and Lessons Learned	Maryland's most successful safety data integration effort has been its integration of crash data and congestion (traffic) data. Maryland's State Highway Administration (SHA) is now able to better strategize and identify its top 3 issues: 1) high speed merges or short weave areas, 2) pedestrians in high congestion areas, 3) at-grade crossings on high speed roads (TRB Circular E-C196).

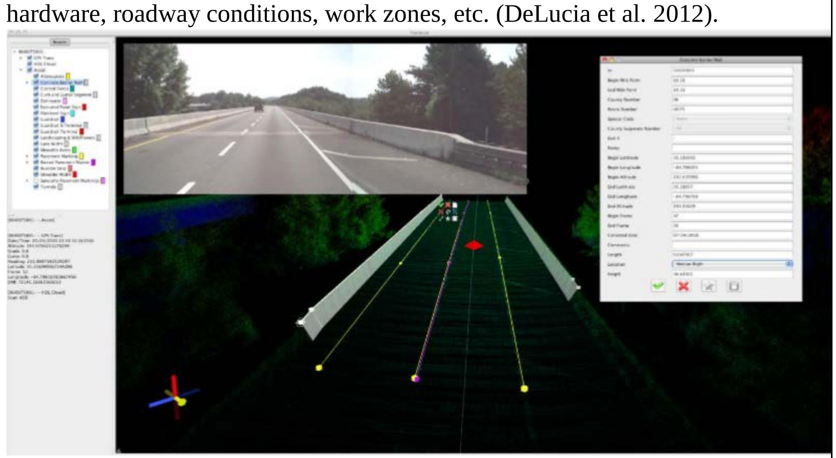
STATE	PHASE	DESCRIPTION
Michigan	Data Collection Efforts	The Transportation Planning division collects roadway data and traffic data. The Michigan State Police collect the crash data and the Bureau of Field Statistics collects maintenance data. The ITS Traffic Operations Centers collect major corridor incident data (TRB Circular E-C196). The Southeast Michigan Council of Governments (SEMCOG) works with local agencies and Michigan DOT (MDOT) to store, verify, and analyze all the data collected. SEMCOG uses 46 validity checks in a Microsoft Office Access database to perform the verification. With 40,355 roadway segments in its jurisdiction, SEMCOG developed an algorithm to estimate the AADT of a segment using the data from nearby counted segments. The algorithm assigns the weighted average of the AADTs of the nearby segments. This reduced the number of short-duration counts that needed to be completed (FHWA Safety Compass Newsletter 2017)
	Data Integration, Maintenance and Management	MDOT is the leader in maintaining and improving quality data, and as a result has streamlined its safety analysis, planning, and decisionmaking processes. Michigan has employed a formal data governance policy—a standard of how data are to be collected, maintained, and interpreted/used. This governance of data has produced better quality data, less duplication of data and overlapping systems, and more workable data for assessment tools yet to come. It is not only important to understand data, but it is perhaps more important to understand what makes data more reliable and useful (FHWA-SA-15-059).
	Challenges and Lessons Learned	Michigan's most successful safety data integration effort has been its development of a statewide crash database, along with Safety Analyst and Roadsoft (TRB Circular E-C196). Roadsoft enabled both MDOT and LPAs to: improve location referencing for crashes on local roads, build consistent maps and data standards for local jurisdictions, share data among agencies of all levels, efficiently conduct safety analyses, and better manage all assets. Improving the Roadsoft tool will require long-term support, LPA access, and incremental updates. A rapid prototyping model enables incremental updates because it would not be designed for only one type of user (FHWA-SA-14-035).
Montana	Data Collection Efforts	Both the Data and Statistics Bureau and the Planning Division collect roadway data and traffic data. The Information Services Division (ISD) collects crash data while the Traffic Safety Engineering Division collects crash data and major corridor incident data. The Maintenance Division collects maintenance data. There is currently no formalized effort for safety program data improvement. The Engineering division completes a safety review of individual project locations in order to identify high risk areas. (TRB Circular E-C196).
	Data Integration, Maintenance and Management	FDEs are included in Safety Information Management System (FHWA HSIP Report 2015, https://safety.fhwa.dot.gov/hsip/reports/pdf/2015/). Traffic Safety Engineering is in charge of SHSP analysis, network screening, identifying and evaluating countermeasures, and HSM predictive analysis. Its safety data workflows have been analyzed, but not mapped. An LRS is available for roadway, crash, and traffic data, and that LRS is compatible with ARNOLD (TRB Circular E-C196).
	Challenges and Lessons Learned	Montana's most successful safety data integration effort has been its Safety Information Management System (SIMS) (TRB E-Circular E-C196).
Nevada	Data Integration, Maintenance and Management	Downloaded crash data are processed through geo-location software and is linearly referenced to the statewide street centerline data (FHWA HSIP Report 2015, https://safety.fhwa.dot.gov/hsip/reports/pdf/2015/).

STATE	PHASE	DESCRIPTION
New Hampshire	Data Collection Efforts	Intersection operation and design is difficult to quantify and address because there is not enough data nor a practical inventory to keep track of necessary data. New Hampshire DOT (NHDOT) was selected by FHWA to lead the Model Inventory of Roadway Elements recommendations released back in 2010 (FHWA-SA-15-087).
	Data Integration, Maintenance and Management	While roadway segments were the major focus for data collection, NHDOT took aim at intersection design elements as well to import them into AASHTOWare Safety Analyst™. This inventory not only provides data-supported safety evaluations but also plays to the economic feasibility of design countermeasures (FHWA-SA-15-087).
	Impacts of Data Integration	Currently NHDOT does not have to default to using dummy values or national averages since it has its own inventory of intersections (FHWA-SA-15-087).
	Challenges and Lessons Learned	Combined with the visuals of a GIS tool like AASHTOWare Safety Analyst™, a collective inventory analysis tool like the AASHTO Highway Safety Manual (HSM), and written standards/guidelines, an LRS as used by NHDOT provides quality and robust data that's easy to understand and communicate. Having a concrete way of formatting input data for use among the different analytical tools improves the accuracy of safety recommendations and countermeasures. Ensuring that quality data goes into the analysis tools leads to more reliable outputs (FHWA-SA-15-058).
New Jersey	Data Integration, Maintenance and Management	With an increasing demand for data-driven decisions, the use of GIS-based has become more prevalent. In the case of the Delaware Valley Regional Planning Commission (DVRPC), GIS-based evaluations could be used to identify dangerous roadway segments or intersections and support plans to alleviate these problems. DVRPC spans two states, Pennsylvania and New Jersey, so it needed to consolidate data formats from both. It also needed to create its own standard criteria for quantifying roadway conditions, doing so using a weighting system. Combining these necessities with the usefulness of GIS provided a clearer image of the safety benefits in potential projects and a priority guideline within the Delaware Valley Region (FHWA-SA-16-029).
New Mexico	Data Integration, Maintenance and Management	In the GIS Data Development and Integration at Navajo DOT pilot project, all of the data compiled by the Navajo Division of Transportation (DOT) led to the need for a pivotal geo-database that would hold all of the GIS data. From that one hub, data can be readily accessible and further managed. This project wanted to figure out the most efficient means of inputting all of the GIS data into the server and, eventually, be able to evaluate the data in order to properly map it and move forward with countermeasures where necessary (FHWA-SA-16-118).
New York	Data Collection Efforts	The New York State DOT (NYSDOT) has led the effort in collecting short-duration traffic counts on local roads. It works with LPAs and MPOs to have them conduct a minimum number of traffic counts annually, depending on the costs. So far, the partnerships have lowered redundancies in data and costs in providing services and support to local agencies (FHWA Safety Compass Newsletter 2017).
	Data Integration, Maintenance and Management	The NYSDOT developed its Enterprise Linear Referencing System. The system contains a compilation of datasets, each of which are based on reference markers. The reference markers allow Shapefiles to be constructed, each containing data such as traffic, bus routes, rail lines, and more. The most recent revisions are of the 2015 data sets. The NYSDOT also conducted a project to collect short-duration traffic counts from local roads and use the counts in a random sample to generate overall statistics for travel on local roadways (FHWA HSIP Report 2015, https://safety.fhwa.dot.gov/hsip/reports/pdf/2015/).

STATE	PHASE	DESCRIPTION
North Carolina	Data Integration, Maintenance and Management	Uses an enterprise data system. The Planning Division enters inventory data from original plans, any changes, and as-builts. The Maintenance Operations Division then makes any changes to data as any changes are made (DeLucia et al. 2012).
North Dakota	Data Integration, Maintenance and Management	A study by Choi et al. (2017) focused on the fastest-growing Native American population in North Dakota, the Fort Berthold Reservation, and the challenge of state and federal roadway data that is inconsistent with local roadway data. The report indicated a lack of roadway data for local roads between the North Dakota GIS Hub (ND GIS Hub) and the federally-funded local roads from the TIGER® product provided by the U.S. Census Bureau. In response to the cited data gaps, this study developed: 1) a navigable road network by improving the connectivity of road segments, updating roadway data, and forming a comprehensive network; and, 2) a standard process for the integration of state and federal data with local roadway data. The standard process developed consists primarily of: 1) combining road segments from each data source; 2) providing legitimacy to the measured distance; and, 3) performing a snapping (measurement of distance) based on the result of the second point to close the gap in between road segments left out of the first point. The results of the study demonstrated that local road data in the Fort Berthold Reservation can be effectively connected through this standard process. The study reported savings both in time and resources and the process developed allows for more efforts to be focused on repairing the road network. The same process can be applied to other Native American Reservation data integration projects and presents a useful process for any data integration projects that suffer from time and fiscal constraints.
Ohio	Data Collection Efforts	Many different bodies oversee the collection of data. The Division of Planning is in charge of collecting roadway, traffic, and crash data, the Office of Technical Services collects roadway and traffic data, the Division of Planning collects crash data, the Division of Operations collects maintenance data and major corridor incident data, the Office of Program Management collects crash data, the Office of Maintenance Administration collects maintenance data, and the Office of Traffic Engineering collects major corridor incident data (TRB Circular E-C196). Funding for data collection comes from a Memorandum of Agreement, which outlines the roles and responsibilities of each county as part of this program. Each county does its part to ensure quality data are collected and shared with the state inventory. Ohio DOT plays the sponsor role, technically supporting and guiding the Location-Based Referencing System (LBRS) development. State and county agencies work together to produce up to date, complete, consistent, and accurate data. The data are even used by emergency services in both response efforts and emergency planning (Ohio Department of Administrative Services 2011).

STATE	PHASE	DESCRIPTION
	Data Integration, Maintenance and Management	The Division of Planning, Office of Program Management, Highway Safety Section oversees the SHSP safety analysis and network screening steps, while each district's respective District Safety Review Team Coordinator is responsible for crash factors, identifying and evaluating countermeasures, and the HSM predictive analysis. Ohio has an LRS in place for roadway, crash, traffic, and asset data, and it is working on one for maintenance data. Ohio is also working on making its LRS compatible with ARNOLD (TRB Circular E-C196). Ohio Geographically Referenced Information Program (OGRIP) recently established the LBRS, a state-county partnership that compiles location information of all public roads in a particular county. The web-based, updated system greatly reduces redundant data collection by individual agencies and makes data available to all stakeholders. The system is also capable of keeping track of crash data, with 99% of all crashes logged in the system compared to 90% of crashes a decade ago. As of December 2016, OGRIP has initiated the inclusion of a few remaining counties in order to complete the project (Ohio Department of Administrative Services 2011).
	Challenges and Lessons Learned	The LBRS has improved location references for crashes on local roads, enabled consistent mapping and data standards across all counties, integrated easily into the state roadway database, made the safety analysis process more efficient, set routine updates of state road mile postings and addresses, and improved data access for the state and counties. Good communication and interaction between the state management and local agencies in charge of collecting local route data are essential for the success of the LRBS (FHWA-SA-14-036).
Oregon	Data Integration, Maintenance and Management	Oregon DOT (ODOT) staff needed to be accessible by all staff, instead of the data each staff was responsible for. As a result, ODOT implemented TransInfo and Features, Attributes, and Conditions – Statewide Transportation Improvements Program (FACS-STIP) Tool, two programs to manage the state's roadway assets. TransInfo is a statewide asset management system that provides ODOT staff with updated asset information highway feature information. FACS-STIP is a web-based program that contains any asset's location, condition, and any other information (FHWA-SA-16-110).
	Impacts of Data Integration	TransInfo and FACS-STIP provide more up to date information in a timely manner. Data are also accessible through a single, uniform system. Maintenance crews can access the data electronically, and it can also be used for review. For the average user, viewing and assessing information based on geo-located assets it's a much more efficient process (FHWA-SA-16-110).
	Challenges and Lessons Learned	The most challenging component of TransInfo and FACS-STIP was the funding. ODOT needed to be strategic with prioritizing its efforts. The Asset Management Steering Committee was established for this purpose. ODOT recommends completing pilot projects first (FHWA-SA-16-110).
Pennsylvania	Data Collection Efforts	The Delaware Valley Regional Planning Commission (DVRPC) has developed the "Traffic Count Viewer," an interactive web tool that allows the public to access traffic data. Users are able to view, filter, and download traffic counts. This tool has been especially useful for transportation engineers, planners, developers, and market analysts. Benefits from the use of the "Traffic Count Viewer" include: increased data collection efficiency thanks to a central database, improved time and cost savings for DVRPC, and enhanced safety analysis (FHWA Safety Compass Newsletter 2017).

STATE	PHASE	DESCRIPTION
	Data Integration, Maintenance and Management	With an increasing demand for data-driven decisions, the use of GIS-based has become more prevalent. In the case of the DVRPC, GIS-based evaluations could be used to identify dangerous roadway segments or intersections and support plans to alleviate these problems. DVRPC spans two states, Pennsylvania and New Jersey, so it needed to consolidate data formats from both. It also needed to create its own standard criteria for quantifying roadway conditions, doing so using a weighting system. Combining these necessities with the usefulness of GIS provided a clearer image of the safety benefits in potential projects and a priority guideline within the Delaware Valley Region (FHWA-SA-16-029).
Rhode Island	Data Collection Efforts	In one of its pilot projects, Rhode Island DOT (RI DOT) needed to also integrate data into a GIS-based system, except it also sought to align its analyses with the recommendations outlined in the Highway Safety Manual (HSM). The data would be compatible with AASHTOWare Safety Analyst™ and the Interactive Highway Safety Design Model (IHSDM) as well. The three stipulations of achieving this goal were as follows: devise a data integration process and how to consistently obtain data, properly govern the data, and demonstrate the effectiveness of GIS-based tools and analysis (FHWA-SA-16-118). Rhode Island is currently undergoing a large data collection effort to obtain all of the MIRE (FHWA HSIP Report 2015, https://safety.fhwa.dot.gov/hsip/reports/pdf/2015/). RI DOT Asset Management is the major body responsible for collecting roadway data, crash data, traffic data, asset data, maintenance data, and major corridor incident data (TRB Circular E-C196).
	Data Integration, Maintenance and Management	RI DOT Traffic Management and Highway Safety oversees the SHSP safety analysis, network screening, crash factors, identifying and evaluating countermeasures, and the HSM predictive analysis. The pilot project should establish a mapping of safety data workflows. An ARNOLD-compatible LRS is available for roadway, crash, traffic, assets, and maintenance data but only for state roads. The DOT is working on expanding it to all roads. The state currently does not have safety-related data management plans or standards in place (TRB Circular E-C196).
South Carolina	Data Integration, Maintenance and Management	South Carolina DOT (SCDOT) and the South Carolina Department of Public Safety (SCDPS) used new funding to implement the South Carolina Collision and Ticket Tracking System (SCCATTS), which aims to improve the quality of its crash data. SCCATTS has improved the accuracy and timeliness of SCDOT's crash data and roadway systems. The system also serves as a common tool for law enforcement and other users to share information (FHWA-SA-16-109).
	Challenges and Lessons Learned	The SCCATTS had been delayed for several years due to a lack of funding. One challenge is that with the SCCATTS, more data are not necessarily indicative of better quality data. As the data was received in a more timely manner, the SCDOT was able to analyze it more quickly and thereby reduce the number of errors in the data. Another challenge was ensuring support from LPAs and law enforcement agencies (FHWA-SA-16-109).

STATE	PHASE	DESCRIPTION
Tennessee	Data Integration, Maintenance and Management	The Enhanced Tennessee Roadway Information Management System (E-TRIMS) is a web-based reporting tool used for extracting roadway inventories, crash data, and project data based on specific criteria. This system enhances the sharing of data by using maps and being user-friendly among state departments, the FHWA, MPOs, RPOs, local governments, consultants, and universities. It contains data for all public roads in Tennessee. Support is split between two major entities. The first is the IT GIS/CADD Office, which makes sure E-TRIMS works as intended. The other is the combination of Roadway Data and Inventory Offices, who are responsible for data analysis, visualization, updates, and data requests. The E-TRIMS application features a wide range of available data. Included are roadway geometrics and features, traffic counts, inventories, project data, structures data, and crash data. It also features tables, such as Road Segment, Route Feature, Roadway Description, and Roadway Geometrics, each of which include corresponding data elements to be sorted and displayed in those tables. Other available tools include Functions (queries, exporting data to other formats, printing reports, etc.) and Reports (traffic, road segments, city mileage, etc.). Furthermore, different layers of the map (boundaries, geographical features, institutions, and more) can be toggled on and off. All of this is made easy thanks to an efficient managing and searching function called Standard Query Language (SQL) (Tennessee Department of Transportation 2013) In 2012, the Tennessee Department of Transportation (TDOT) accomplished its initial data collection for its entire roadway network, which includes all interstates, state highways, arterials, collectors, and local roads. With these data, TDOT created a horizontal curve database with approximately 40,000 miles of roadways (comprising approximately 20% of the total roadway system) with curves (FHWA-SA-16-048). An illustration of Tennessee's LiDAR system can be found below in Figure A3. It helps the DOT collect data and create specialized inventories such as hardware, roadway conditions, work zones, etc. (DeLucia et al. 2012).  FIGURE A3 Roadway view using LiDAR - Tennessee DOT (DeLucia et al. 2012).

STATE	PHASE	DESCRIPTION
Utah	Data Integration, Maintenance and Management	UDOT developed UPlan in order to have a helpful, user-friendly online mapping tool. All over the state, it provides interactive maps and data where permitted for planning and execution of projects. Its data collection practices, including LiDAR, digital imaging, workstation, and ArcGIS are common among the majority of other states. UPlan is based off United States Road Assessment Program (usRAP) procedures, tools used by transportation agencies to quantify the safety and condition of their roads. usRAP targets crash and roadway data to assign a risk factor to the different adjustments that could be made to any of those roads. Together, UPlan and usRAP offer data-supported decision assessments in a language that can be understood by the general public (FHWA-SA-16-028).
	Impacts of Data Integration	UPlan serving as the hub of for mapping, interactive information, and subsequent planning and decisionmaking provides benefits for all of those within and working with UDOT. With minimal effort, it is possible to obtain necessary data and information, quickly and efficiently communicate it with employees and partners, and be wary of resource allocation (FHWA-SA-16-028). The practicality of the UPlan web-based mapping and informational tool is further strengthened thanks to data management strategies employed by UDOT. Its notice of need for a formal data governance plan like that of MDOT has led the state to similar conclusions: streamlined data supports the progression of safety analysis, sets performance standards, regulates the wide variety of data, and emphasizes the cooperation factor between strategists, IT developers, and other parties involved. UDOT’s willingness to improve its data governance and connect the refined data to its performance goals and standards makes it a model for other state DOTs to follow suit (UDOT 2014).
Virginia	Data Collection Efforts	Virginia DOT uses a trip generation method to estimate AADT on local roadways. This method was developed as a results of efforts to reduce data collection costs and to reduce staff effort. The Regional and District Office staff review the roadway systems and estimate the number of trips between locations in order to determine the volume of the segment. The benefits of the trip generation include reduced data collection costs, fewer resources necessary, and a time savings due to the efficiency of the method (FHWA Safety Compass Newsletter 2017).
Washington	Data Collection Efforts	The Transportation Data and GIS Office collects roadway data, crash data, and traffic data. The Washington Incident Tracking System collects major corridor incident data. Several different groups oversee the individual components of asset data and maintenance data (TRB Circular E-C196).
	Data Integration, Maintenance and Management	The Washington State Traffic Safety Commission (WTSC) is in charge of SHSP safety analysis, while the Capital Program Development and Management Office oversees the network screening. Determining factors of crashes, identifying and evaluating countermeasures, and the HSM predictive analysis all take place across multiple offices in the DOT. They are not always centralized. As part of the strategic plan for sustainable highway safety, Washington has mapped its safety data workflows. Additionally, there is an LRS in place. The Transportation Information Planning and Support System (TRIPS) tracks the LRS weekly. The system is updated annually. Safety-related management plans are in place (TRB Circular E-C196). The *Feasibility Study for GIS Based Roadway Data Integration* was conducted to evaluate the feasibility of integrating roadway data at the state and federal level. The study concluded that integration will need constant leadership to make integration projects happen (Transcend Spatial Solutions 2015).

STATE	PHASE	DESCRIPTION
	Challenges and Lessons Learned	Washington’s most successful safety data integration effort has been crash data integration. The state is now making decisions on LED conversion, lighting system removal, and damaged pole removal (TRB Circular E-C196). The major challenge for Washington’s data integration is that integration is done by individual businesses instead of by the enterprise (TRB Circular E-C196). Effective data integration is limited due to a lack of incentive or initiative. Furthermore, data integration requires sufficient funding, technology, staff resources, and focused directives that are in accordance with other parties and agencies (Transcend Spatial Solutions 2015).
Wisconsin	Data Collection Efforts	The Wisconsin Information System for Local Roads (WISLR) was successfully developed by the state in the 1990s as a safety and asset management system. Its goal was to meet the needs of local stakeholders, which meant the new system had to be developed similar to the confines of the one in use for state roads. As a result, the state roadway data could be integrated with the local roads to create a database that included all public roads. WISLR complies spatial location, asset, inventory, and crash information thanks to an “on/at/towards” LRS. It is available to anyone with authorization, with local agencies taking care of data collection within their jurisdiction and forwarding it to the central system. So far, WISLR has produced consistent statewide local roadway data, saved money by reducing redundancy, expanded the role of local agencies, provided an efficient tool for safety analysis, and drawn up an all public roads LRS and base map (FHWA-SA-14-037).
	Data Integration, Maintenance and Management	Wisconsin Department of Transportation (WisDOT) employs two linear referencing systems to manage its roadway data. The first of the two, the State Trunk Network (STN), is limited to state routes—interstates, USH, and state highways. The second LRS is the Wisconsin Information System for Local Roads (WISLR). While it does include all roads, its focus lies in county and local roads. The problem is neither system relates to the other. Their IDs for road segments and intersections to not follow the same format. (Ryals 2010). The Bureau of Planning and Economic Development (BPED) Statewide Planning Unit wanted to resolve its problematic manual methods for processing State Trunk Highway Network (STN) data. Data processed in this manner was redundant and inconsistent, and the process itself took a while. The Statewide Planning Unit launched the Lean Six Sigma project to improve data processing time and accuracy. Their main tools included: suppliers, inputs, processes, outputs, and customers (SIPOC) identification to grasp the STN data process, performing a Kano analysis to decide what outputs would meet the needs of employees, and mapping a value stream to pinpoint redundant components and improve them (Wisconsin DOT 2014).
	Impacts of Data Integration	This new automated process reduced processing time by 56%, from 31.5 minutes to 13.8 minutes per dataset. When processing the six datasets (each based on roadway functional classifications), the overall processing time dropped by 83% from 3.2 hours to 0.5 hours. Formerly manual steps were reduced as well. Updating GIS tools also enabled more accurate data to be produced for map and system usage. Now, the Statewide Planning Unit can focus on evaluation and employing standard operating procedures to adapt the data and methodology (Wisconsin DOT 2014).

STATE	PHASE	DESCRIPTION
	Challenges and Lessons Learned	It was necessary to merge the two systems because important transportation data needs to be easily transferable between them. In order to do so, a "link_link table" was created as part of a pilot study to match up corresponding IDs for a certain segment or intersection. This did not require extensive changes to or abandonment of a particular system already in use, and it instead combined the abundance of data from both systems. With effective quality control and coding, WisDOT brought both systems into a common denominator (Ryals 2010).

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