



SCAN TEAM REPORT

NCHRP Project 20-68A, Scan 09-03

Best Practices In Lane-Departure Avoidance And Traffic Calming

Supported by the

National Cooperative Highway Research Program

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SPECIAL NOTE: This report IS NOT an official publication of the National Cooperative Highway Research Program, Transportation Research Board, National Research Council, or The National Academies.



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The purpose of each scan and of Project 20-68A as a whole is to accelerate beneficial innovation by facilitating information sharing and technology exchange among the states and other transportation agencies, and identifying actionable items of common interest. Experience has shown that personal contact with new ideas and their application is a particularly valuable means for such sharing and exchange. A scan entails peer-to-peer discussions between practitioners who have implemented new practices and others who are able to disseminate knowledge of these new practices and their possible benefits to a broad audience of other users. Each scan addresses a single technical topic selected by AASHTO and the NCHRP 20-68A Project Panel. Further information on the NCHRP 20-68A U.S. Domestic Scan program is available at

<http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1570>.

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Disclaimer

The information in this document was taken directly from the submission of the authors. The opinions and conclusions expressed or implied are those of the scan team and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors. The document has not been edited by the Transportation Research Board.



Scan 09-03

Best Practices In Lane-Departure Avoidance And Traffic Calming

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ABBREVIATIONS AND ACRONYMS

Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
CDART	Crash Data Analysis and Retrieval Tool (PennDOT)
CLRS	Centerline Rumble Strips
CDOT	Colorado Department of Transportation
CMB	Cable Median Barrier
CRISOS	Crash Reduction by Improving Safety on Secondaries Program (now the SCDOT State Rural Road Safety Program)
CRSP	County Road Safety Plan
CTRE	Center for Transportation Research and Education
ELRS	Edge line Rumble Strips
EMS	Emergency Medical Services
FASTER	Funding Advancements for Surface Transportation and Economic Recovery (CDOT)
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
GEARS	Georgia's Electronic Accident Reporting System
HSIG	Highway Safety Issues Group (WSDOT)
HSIP	Highway Safety Improvement Program
LOSS	Level of Service of Safety (CDOT)
LTAP	Local Technical Assistance Program
MDOT	Michigan Department of Transportation
MnDOT	Minnesota Department of Transportation
MoDOT	Missouri Department of Transportation

ABBREVIATIONS AND ACRONYMS

NCHRP	National Cooperative Highway Research Program
PennDOT	Pennsylvania Department of Transportation
ROR	Run-off-road
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SCDOT	South Carolina Department of Transportation
SHSP	Strategic Highway Safety Plan
SPF	Safety Performance Function (CDOT)
SRS	Shoulder Rumble Strips
TEA-21	Transportation Efficiency Act of the 21st Century
TEAP	Traffic Engineering Assistance Program (Iowa DOT)
TRB	Transportation Research Board
TSR	Traffic Safety Review (Mendocino County)
WSDOT	Washington State Department of Transportation

Executive Summary

Scan Overview

This domestic scan was developed from proposals of state highway engineers concerned about the unacceptable levels of run-off-road crashes, injuries, and fatalities on the nation's highways. The scan team's mission was to identify transportation agencies with successful solutions to lane departures, to be educated on those solutions, and to disseminate information from these promising programs to other transportation agencies.

The scan tour's scope was further restricted to low-cost measures on high-speed rural roadways. The scan team also chose to focus primarily on engineering solutions through standard engineering practices instead of on education, enforcement or emergency-response strategies.

The team's members were:

- Mark Nelson, North Dakota DOT, AASHTO chair
- John P. Miller, Missouri DOT
- Ina Zisman, Colorado DOT
- Cassandra Isackson, Minnesota DOT
- Daniel Helms, Mississippi DOT
- Richard B. Albin, FHWA
- Dean Focke, subject matter expert

The team chose to focus on the following program categories as topics of interest; specifically, transportation agencies:

- That have advanced highway safety programs
- That employ systematic countermeasures (i.e., proactive measures)
- With proven successes in mitigating lane departures
- That have implemented low-cost programs

The scan travel schedule was as follows:

- Week 1, November 14–20, 2010
 - The team traveled to Detroit for a Monday meeting with Michigan DOT (MDOT), followed by a Tuesday meeting with Pennsylvania DOT (PennDOT), and a Wednesday meeting with South Carolina DOT (SCDOT).

- On Thursday, the scan team traveled to Georgia for a field visit with Georgia DOT (GDOT) personnel in Carroll and Douglas Counties. The Team ended the week at GDOT, and concluded with a strategy session late Friday afternoon.
- Week 2, November 28–December 5, 2010
 - The team met in Minnesota DOT (MnDOT) in Minneapolis on Monday morning, followed by an afternoon field visit to Wright County, Minnesota, hosted by the Wright County engineer. MnDOT finished its presentation to the scan team Tuesday morning. Iowa DOT followed with a presentation of its own at the Minneapolis location.
 - On Wednesday, Colorado DOT (CDOT) hosted the team, including site visits in Clear Creek and Summit Counties. CDOT finished its discussion on Thursday morning. In the afternoon, the Mendocino County, California, engineer made a presentation to the team.
 - The team had an all-day meeting with Washington State DOT (WSDOT) on Friday
 - On Saturday, the team held a final meeting to summarize the scan tour and develop an implementation plan.

Summary of State and County Discussions

The following highlights are a brief summary of the topics the scan team discussed at each venue. They are listed in the order in which the hosting agency presented them.

Michigan

- **Cable median barrier** – MDOT has installed 180 miles of high-tension cable and plans to install 100 more miles in freeway medians. Using Highway Safety Improvement Program (HSIP) funding, 75% of the cable projects are standalone projects.
- **Rumble strips** – MDOT has installed 5,400 miles of centerline rumble strips (CLRS) and 2,700 shoulder miles of non-freeway shoulder rumble strips on existing pavements. The strips are used on pavement in all conditions, even chip-seal and crack-sealed pavement.
- **Delineation** – MDOT has a test program in place that is using proprietary products for continuous line delineation on guardrail and barriers.
- **Local safety** – Michigan Local Technical Assistance Program (LTAP)¹, in cooperation with MDOT, enhanced the RoadSoft Safety Module² to assist local agencies in identifying targeted safety locations. The module provides detailed safety analyses and integrates crash data into reporting features and collision diagrams. Through

¹ National Local Technical Assistance Program/Tribal Technical Assistance Program (LTAP/TTAP), <http://www.ltap.org/>

² RoadSoft GIS, <http://www.roadsoft.org/>

MDOT's Local Safety Initiative³, safety engineers provide traffic-engineering services to local agencies, advising them on road safety issues and providing funding application assistance.

- **High-friction pavement** – Five spot locations are using high-friction pavements as part of an FHWA program. MDOT is also evaluating this treatment in various other locations beyond the FHWA program.
- **Road diets** – Michigan is in the initial stages of researching road diets. One of the deliverables, guidance on when to convert a roadway, will be applicable to local agencies. MDOT has converted 44 corridors, having a combined length of 46 miles, as a means of addressing crashes.
- **Traffic signing** – The state has an aggressive 15-year replacement program for signs, using the latest standards, including the Clearview font⁴. For improved emergency response times, the state is installing enhanced reference location signs at one-mile spacing on rural freeways and 0.2-mile spacing on urban freeways. Upon the request of local emergency services, Michigan is considering placing these signs at 0.2-mile spacing on rural freeways.
- **Public outreach** – MDOT developed “Median Man” public service announcements as part of public education on cable median barrier. MDOT developed a first responder flyer and video, which are educational tools on the correct procedure for approaching a crash site involving cable barrier.

Pennsylvania

- **Administrative** – PennDOT is a decentralized department, having 44,000 miles of state roads and 78,000 miles of local roads. Local roads account for about 20% of the fatalities. A strong centralized safety group makes safety a component of every project. The Multi-Agency Safety Team (MAST) is made up of various stakeholders with a common interest in highway safety.
- **Safety programs** – PennDOT has established a low-cost safety improvement program to drive safety project selection. It uses measurable and accountable performance measures to instill a culture of safety statewide.
- **Lane-departure issues** – As with many of the states visited by the team, bicycling groups in Pennsylvania have concerns about the use of shoulder and edge line rumble strips (ELRS). The state has reached out to the cycling community to gather wider support. Pennsylvania has installed 3652 miles of shoulder/ELRS. Run-off-road fatalities in the state have fallen from an average of 703 annually over the last five years to 665 in 2010. The state has installed 4,405

³ MDOT Local Safety Initiative, http://www.mi.gov/mdot/0,1607,7-151-9615_11261_45212---,00.html

⁴ Clearview is a registered trademark of Terminal Design, Inc., <http://www.clearviewhwy.com/>

miles of CLRS. Head-on fatalities have dropped from an average of 180 per year over the last five years to 175 in 2010. CLRS are placed only in no-passing zones.

- **Data management** – The Crash Data Analysis and Retrieval Tool (CDART) is a Web-based query tool and reporting application with the ability to present crash data in several formats, including maps, spreadsheets, reports and data files. The application allows the user to write queries using Crash Reporting System⁵ data from 1997 to the current time.
- **Countermeasures** – Pennsylvania is currently deploying a statewide process of systemic improvements, including rumble strips and curve-related improvements. The state is also performing a benefit-to-cost ratio study of cable median guiderail and horizontal curve treatments (advance curve-warning markings). Pennsylvania has an active tree removal/trimming and utility pole relocation program to reduce frequently hit fixed-object crashes.

South Carolina

- **Administration** – SCDOT is a centralized department with responsibility for 40,000 miles of state highways. Approximately 95% of the fatalities occur on the state system versus 5% on 20,000 miles of local roads.
- **Safety program** – All projects must be prioritized and have a good benefit-to-cost ratio to be considered. SCDOT receives safety funding from the state government, in addition to federal HSIP funding.
- **Strategies** – South Carolina has finished a 10-year program installing cable median barrier on all of the warranted interstate highways (i.e., 400 miles). The state has added approximately 1,000 miles of two-foot-wide paved shoulders over the last five to six years.
- **Data analysis** – About 50% of all fatalities are lane-departure related. To address safety on its high mileage of rural roadways, the state developed the Crash Reduction by Improving Safety on Secondaries (CRISOS) program (now the State Rural Road Safety Program), allowing more resources to be used on lower volume roadways.
- **Countermeasures** – SCDOT uses a profiled edge stripe instead of the milled rumble strip. A two-foot width of paved shoulder widening is now the standard for roadways that previously did not have a paved shoulder. Dashed edge lines traversing through intersections are used as guidance lines for drivers.
- **Enforcement and education** – In a joint effort with Department of Public Safety for both enforcement and education, SCDOT uses radio ads, television ads, and press releases to educate the public about lane-departure issues. The state stringently enforces speeding, seatbelt, and DUI laws.
- **Challenges** – The two primary challenges SCDOT faces are the public's perception of noise

⁵ Crash Reporting System, <http://www.dot.state.pa.us/crash>

generated by rumble strips and developing trust and a working relationship with bicycling groups.

Georgia

- **Local agency off-system program** – In Georgia, 45% of fatalities are off-system. Because \$7 million is available for off-system safety improvements, the local agencies need no matching funds. Many counties do not have engineers, so GDOT provides road safety audits and other assistance to them so that they are able to apply for safety funds. As much as 95% of off-system projects are limited to low-cost signing, striping, and installing raised pavement markers.
- **Safety edge** – GDOT led the nation with the development of the safety edge. The safety edge is now policy, with standards and specifications established and used on all projects.
- **Horizontal curves** – GDOT is developing a program to address priority curves with high-friction pavement and/or warning signs and chevrons.
- **Rumble strips** – GDOT takes a systemic approach to rumble-strip installation as part of yearly resurfacing projects by using crash data to determine locations. It also installs CLRS, but avoids using shoulder and CLRS in the same location.
- **Crash data** – In 2005, GDOT took ownership of all crash data and is striving to improve its reliability and timeliness. About 34% of crash data is now entered into the electronic database. In return for modernizing the data collection, a private vendor has rights to sell the data (in the form of crash reports). This is done at no cost to GDOT.

Minnesota

- **Toward Zero Deaths program** – Toward Zero Deaths is a partnership to create a culture in which traffic fatalities and serious injuries are no longer acceptable. MnDOT is doing this through the integrated application of education, engineering, enforcement, and emergency medical and trauma services. These efforts will be driven by data, best practices, and research. Minnesota has 141,000 miles of roads, with 11,000 miles of state trunk highway and 900 miles of interstate. Half of the severe crashes are on trunk highway, half on local roadway.
- **County roadway safety program** – One-half of all crashes happen on the 45,000 miles of Minnesota's county highways. County roadway safety plans are being completed and used to identify low-cost systemic safety projects to address the most severe types of crashes found on these roadways. MnDOT provides funding to use proven strategies, but will also consider tried and experimental strategies on occasion; both reactive and proactive strategies are used. The agency identifies surrogates to determine high-risk segments, curves, and intersections on rural roads to implement systemic countermeasures.
- **Horizontal curves** – Curves are over-represented on lane-departure crashes. In Minnesota, most curve crashes are on paved roads, with a radius between 500 and 1500 feet, and an average daily traffic (ADT) of between 500 and 1500 vehicles. Minnesota can identify curve radius inexpensively on the Web by using Google Earth⁶. MnDOT has found that the most

effective countermeasure is to install shoulder widening and shoulder rumble strips along with chevron signing.

Iowa

- **Rural traffic calming** – A recent traffic calming study looked at a handful of sites in small rural communities, each town using a different set of devices (e.g., pavement markings, lane narrowing, optical speed bars, and speed tables). The results were mixed. The researchers found that sometimes the community did not accept the proposed or installed traffic-calming countermeasure.
- **Rumble stripes** – Four- to six-inch rumble stripes are used in locations where there is no paved shoulder or only a very narrow one. Locations where there is an offset between the stripes and the pavement edge yield better results.
- **Pavement edge drop-offs** – A study of over 230 sites in two states found that drop-offs became a problem for drivers at depths of two or more inches.
- **Safety edge** – Iowa specifies the use of a safety edge on highways with less than a four-foot paved shoulder. The DOT has found that contractors choose to use safety edge to mitigate maintenance of traffic control requirements (e.g., end-of-work-day shoulder buildup).
- **Safety plans** – Iowa DOT provides traffic engineering assistance (i.e., traffic-related studies) to small communities and counties.

Colorado

- **Safety programs** – Colorado has 9,000 centerline miles of state-maintained system; the counties have 47,000 miles (only 12,000 miles are paved). Sixty percent of fatalities occur on the state system. The state's Funding Advancements for Surface Transportation and Economic Recovery (FASTER)⁷ legislation uses state funds from licensing fees to fund safety projects.
- **Managing safety** – The Safety Assessment Program is centralized and institutionalized. Safety assessments are available for the entire system and are done on every project at scoping. CDOT has developed a level of service for safety and applies a pattern recognition algorithm to identify effective countermeasures.
- **Countermeasures** – CDOT has installed rumble strips on all rural interstate highways, and the agency has an ongoing cable median barrier program. Dynamic wildlife detection systems are being studied along 100 miles of wildlife corridors. An advance curve-warning system at one location with five curves has provided good results so far, but more data is needed.
- **Education** – CDOT funded a smart phone application that allows users to calculate their blood-alcohol level.

⁶ Google Earth, <http://www.google.com/earth/index.html>

⁷ FASTER, <http://www.coloradodot.info/projects/faster>

Washington State

- **Target Zero** – The Washington Traffic Safety Commission administers the Target Zero program, for which impaired drivers, speeding, and run-off-road fatalities are the highest priority. Infrastructure improvements are not a solution for the majority of crashes – the other 4 E’s of highways safety (i.e., enforcement, education, and emergency medical services) are more effective.
- **Highway Safety Issues Group** – WSDOT does not have a designated safety engineer. Instead, the Highway Safety Issues Group (HSIG) is a coordinated and proactive roadway safety approach, which includes a team of safety experts, advocates, and executives that meets monthly to discuss safety issues. The group encourages buy-in from all agency regions and programs to allow implementation of safety policy. An executive team provides leadership direction, and the team membership consists of the state risk manager, design engineer, traffic engineer, program manager, highways and local programs director, and the maintenance engineer.
- **Local agency involvement** – The state has mapped all local roads and can provide detailed crash analysis for each of its 39 counties. With this information, Washington has determined that two-thirds of all crashes on the local system are run-off-road and has furthered identified prioritized sections for targeted safety projects.
- **Systemic countermeasures** – WSDOT spent 15 years getting all highway data into electronic format. The agency uses it to show the legislature that WSDOT is doing the right projects in a cost-effective manner. Systemic improvements include updating guardrail to standards and installing cable median barriers, rumble strips, and an inventory of roadside features.

Wright County, Minnesota

- **Local issues** (typical of local transportation agencies nationwide) – Generally, much of the county road networks do not meet current engineering standards and it would be very costly to upgrade to current standards. Local government executives may make decisions that take into account factors other than highway safety concerns. Limited funds dictate many of the safety solutions available to local transportation agencies. Creative low-cost solutions can provide useful tools for the local highway engineer/supervisor.

Mendocino County, California

- **Road system traffic reviews** – Data analysis is unrealistic because of low traffic counts and small statistical samples on county roads. These reviews were developed as a low-cost effort to identify and treat collision generators systemically and stretch resources to maximum limits.

Preliminary Findings

Lane-Departure Countermeasures

The team focused on these relatively low-cost initiatives taken by transportation agencies to mitigate the causes and effects of lane departures:

- Shoulder rumble strips (SRS)
- Centerline Rumble Strips (CLRS)
- Edge line rumble stripes (ELRS)
- Safety edge and pavement drop-offs (especially high-severity drop-offs)
- Paved shoulder widening
- Edge line pavement markings
- Pavement markings at curves
- Additional signing, especially at horizontal curves
- Dynamic signing (e.g. speed feedback and light-emitting diode [LED] illuminated signs)
- Cable median barriers
- Removal of frequently hit objects (e.g., trees and utility poles)

Successful agencies not only addressed “hot” or “black” spots in identifying crash locations (i.e., reactive), but they also realized that being proactive is an effective use of funding. Proactive countermeasures work well with systemic treatments for proven countermeasures. Some agencies were active in applying promising and innovative countermeasures at problematic spot locations.

Accurate and Timely Crash Data and Data Analysis

Having appropriate and available crash data was another critical issue agencies face. Departments adept at processing crash data are better able to allocate scarce resources. These agencies had experienced a variety of problems with data, ranging from uncertainty about who “owns” the data, lack of confidence in the accuracy of the crash reports, the inability to input the data electronically (especially geographical coordinates), difficulties with data timeliness and ease of querying, and the inability to generate reports and maps of various formats.

Performance Reviews

The scan team found another factor that is necessary to attain continuous safety improvements is the use of meaningful and relevant performance measures. Agencies that deliver constant program data seem better able to find and eliminate deficiencies.

Funding Issues and Resources

Funding of countermeasures was an issue everywhere; however, successful agencies do manage

to find safety money. Sources include SAFETEA-LU⁸, state set asides, and other methods, such as Section 154⁹ or Section 164¹⁰ funding.

Institutionalized Culture of Safety

During its visits, the team noticed that a transportation agency's organizational culture had a direct and positive correlation with the success of various countermeasures for mitigating the effects of lane departures. The most basic of these correlations was the presence of an advocate within the agency who made it a personal mission to improve safety. Usually the advocate was directly involved in safety programs and in a position to effect changes in the agency's status quo.

A second correlation found in successful agencies was institutionalizing safety by taking successful strategies and codifying them into departmental policies (e.g., directives, standard operating procedures, standard plans, and design manuals). Not only does formalizing countermeasures result in wider acceptance, but it also has an added benefit of providing future continuity of the safety program within a department if the advocate retires or otherwise leaves the position.

Finally, top-performing transportation agencies strive to encompass safety in every aspect of the department. From planning and design to funding, construction, and beyond, these departments embrace safety from top-management staff down to hourly workers. The amount of resources that these agencies devote to safety is enormous. These organizations take highway safety from a lower-level program and advance it into a system-wide culture.

Partnerships

This scan looked primarily at engineering solutions; however, the team found that agencies with successful safety programs were more likely to team up with other interested parties in an effort to utilize the 4 E's of highway safety: engineering, enforcement, education, and emergency medical services.

⁸ Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users, <http://www.fhwa.dot.gov/safetealu/>

⁹ Section 154 Open Container Transfer Provision, <http://www.statehighwaysafety.org/html/stateinfo/programs/154.html>

¹⁰ Section 164 Repeat Offender Transfer Provision, <http://www.statehighwaysafety.org/html/stateinfo/programs/164.html>

Introduction

Following the publication of NCHRP Report 500, Volume 6, *A Guide for Addressing Run-Off-Road Collisions*¹¹, in 2003, many state transportation agencies have identified lane departure as an action area in their state's Strategic Highway Safety Plan, a major component and requirement of the HSIP. In April 2008, American Association of State Highway and Transportation Officials (AASHTO) published *Driving Down Lane Departure Crashes—A National Priority*¹². This document highlighted a number of lane-departure remedies that emphasize the need to more actively address the causes of lane-departure crashes and develop/implement countermeasures to reduce them.

A number of states have implemented measures from these publications; however, the nature and effectiveness of these measures are not widely disseminated. The scan team conducted a desk scan to identify agencies that have implemented lane-departure strategies, either system-wide or at spot locations and have evaluated the effectiveness of these strategies in crash reduction. The scan also searched for implementation costs of the countermeasures, and their impact on road users. The scan team developed and sent a list of Amplifying Questions (see Appendix A) to the host agencies prior to the scan tour. Host agency key contact information is provided in Appendix B.

Information obtained from this scan will provide state and local engineering agencies with information on strategies other agencies are using successfully to address lane-departure safety issues. This information will be particularly important to those who are responsible for highway safety on high-speed highways and will greatly assist them in producing strategies that will reduce highway fatalities associated with these types of crashes.

The seven member scan team consisted of one representative from FHWA, five representatives from state DOTs, and a subject matter expert. Contact information and biographical sketches are given in Appendix C and Appendix D, respectively.

Host Agency Information

Michigan

Michigan has a population of 9,970,000. Its state-owned roadway mileage is 9573, which represents approximately 8% of the total roadway miles in the state. In 2006, Michigan recorded 315,322 crashes, resulting in 81,942 injuries and 1084 fatalities.

Forty percent of Michigan's fatal and severe injury crash types are related to lane departure. Michigan DOT (MDOT) believes that lane departure is a serious problem and that many of

¹¹ Volume 06: A Guide for Addressing Run-Off-Road Collisions, <http://safety.transportation.org/guides.aspx?cid=27>

¹² Driving Down Lane-Departure Crashes—A National Priority, <http://downloads.transportation.org/PLD-1.pdf>

these crashes can be mitigated.

Pennsylvania

Of all the states the scan team visited, Pennsylvania' ranked at the top in three areas:

- The most populated, at 12,600,000
- The highest population density, at 274 people per square mile
- The most number of licensed drivers, at 8,370,000

There are 121,581 miles of public roadway in the state; Pennsylvania DOT's (PennDOT's) portion is 39,871 miles.

Based on Fatality Analysis Reporting System¹³ figures, Pennsylvania ranked fifth in the nation in 2007, with 847 road-departure fatalities, 56.8% of all highway fatalities in the state. In 2009, the state showed a 15% reduction in traffic-related fatalities, with 1256 fatalities compared to 1468 in 2008. The system-wide deployment of projects through PennDOT's Low-Cost Safety Improvement Program¹⁴ contributed to reducing crashes almost 9% over the past five years.

South Carolina

With a population of 4,560,000, South Carolina ranks as the 24th most populated in the country. South Carolina DOT (SCDOT) manages 41,437 miles of roadways, a substantial 62.5% of the state's 66,248 miles of public roadways.

More than half of all fatal crashes in South Carolina involve a vehicle running off the road. A run-off-road (ROR) crash occurs every 30 minutes on average, and one person dies in one of these crashes every day.

In 2007, South Carolina ranked tenth in the nation, with 674 lane-departure fatalities, 63% of all highway fatalities in the state, based on Fatality Analysis Reporting System figures. During the five-year period of 2004 to 2008, there were 134,975 lane-departure crashes in South Carolina, resulting in 2794 deaths and 59,029 nonfatal injuries. Roadway-departure fatalities represent 54% of all crash fatalities. The leading causes for lane-departure crashes in South Carolina (2004–2008) were:

- Too fast for conditions (49,284)
- Improper lane change (15,346)
- DUI (12,646)
- Driver inattention (9379)

¹³ Fatality Analysis Reporting System, <http://www.nhtsa.gov/FARS>

¹⁴ PA Traffic Safety Information Center, <http://www.drivesafepa.org/Traffic-Safety-Information-Center/Infrastructure/>

-
- Failure to yield (6286)
 - Running off the road (5214)

These crashes resulted in 2794 deaths, with the leading causes for lane-departure crash fatalities (2004–2008):

- Too fast for conditions (968)
- DUI (841)
- Running off road (228)
- Wrong side of road (225)
- Falling asleep (78)
- Driver inattention (69)
- Aggressive driving (63)

South Carolina is one of 17 FHWA roadway-departure focus states. This report addresses findings from five other focus states: Pennsylvania, Mississippi, Missouri, Iowa, and Washington.

South Carolina currently ranks as one of the top 10 states for highest percentage of ROR fatalities. The estimated annual cost of ROR crashes in South Carolina was nearly \$1 billion in 2008.

Georgia

Georgia is a fast-growing state, and its 26.4% 10-year growth rate and large population (9,830,000) keeps the Georgia DOT (GDOT) in a constant state of flux.

In 2003, there were 451 single-vehicle ROR fatal crashes statewide. There were 30,013 total ROR crashes for the state's on-system and off-system routes combined. The fatal crashes accounted for approximately 0.14% of all crashes that year, and total ROR crashes accounted for just over 9% of the total number of crashes. Based on Fatality Analysis Reporting System figures, in 2007, Georgia ranked fourth in the nation, with 874 roadway-departure fatalities, or 53.3% of all highway fatalities in the state.

One-quarter of all traffic fatalities in Georgia result from vehicles leaving the road and hitting a fixed object or overturning. Although it is important to develop methods to keep vehicles from leaving the roadway, the state believes that it is also important to try to minimize the impact for those that inevitably do.

Eighty-five percent of Georgia's 118,778 miles of public roadways are on the local system. The state has implemented a local agency off-system program to address the fact that 45% of the fatalities are off-system.

Minnesota

Minnesota has 87 counties and a population of 5,270,000. Although there are 137,693 miles of

public roads, most of them (119,310 miles) are rural. The state ranks 48th in the United States in the number of licensed drivers per capita.

Minnesota's Strategic Highway Safety Plan¹⁵ (SHSP) identifies single-vehicle road-departure crashes as one of the state's safety emphasis areas because these types of crashes account for 32% of fatal crashes.

There are 52,000 miles of rural two-lane highway (8,000 miles on the state system and 44,000 miles on local systems). One-half of all crashes occur on the 45,000 miles of county highways, while the other half occurs on only 11,000 miles of trunk highways.

For the third consecutive year, Minnesota's annual traffic death toll fell in 2010 to 411, the lowest count since 1944. The Department of Public Safety reported 74,073 traffic crashes involving 134,414 motor vehicles, 182,672 people, and 31,176 injuries.

Wright County, Minnesota

Wright County is one of the fastest-growing areas of the state, due to its proximity to the Minneapolis-St. Paul metropolitan area. It covers 716 square miles in the east-central part of the state, and about 69% of it is classified as agricultural. In 2009, its total estimated population was 120,684. Most of the severe crashes in Wright County are roadway-departure crashes.

The scan team visited Wright County to hear local agencies' concerns about roadway-departure safety. These issues are significantly different from those of a state- or national-level organization, and the scan team was interested in learning about the differences. Wright County's experiences are quite similar to those of most of the other 3,100 county jurisdictions in the United States:

- County roadway networks are not all meeting current engineering standards, and it would be very costly to upgrade to current design standards.
- The political reality is that some decisions are made by the elected County Commissioners and may not always be in the best interest of highway safety.
- Limited funds dictate many of the safety solutions that are available to local transportation agencies.

Iowa

Iowa was the least populated state on the scan tour: its population of 3,010,000 ranks it 30th in the country. It also had the least amount of state highway mileage (8878 miles) of the states on the tour; however, it has a healthy amount of public roads mileage overall, at 114,193 miles.

An Iowa State University/Center for Transportation Research and Education (CTRE) study found that 12% of fatal and 15% of severe injury crashes in the state occur on curves, and that 56% of fatal ROR curve crashes are speed related.

¹⁵ Minnesota Strategic Highway Safety Plan, <http://www.dot.state.mn.us/trafficeng/safety/shsp/index.html>

Iowa’s highway safety stakeholders believe that “one death is one too many” and that an effective culture-changing policy and program strategies must be implemented to help reduce the state’s death toll from an annual average of 445 to 400 by the year 2015.

In recent years, Iowa DOT’s leadership has been very open to significant changes and letting go of past practices. These changes include spending safety funds on local (i.e., city or county) roads, paving more shoulders, and installing rumble strips/stripes (i.e., on shoulders and centerlines).

Colorado

Colorado is the fastest-growing state on the tour, growing 31% over the past 10 years and a population estimated at 5,020,000 in 2009. Even though Colorado was the largest state on the tour by area (104,000 square miles), Colorado DOT (CDOT) has responsibility for just 9,092 centerline miles of state highway; 60% of fatalities occur on the state system. Colorado counties have 47,000 miles of roadway; however, only 12,000 miles of them are paved roads.

The number of fatal crashes dropped 41% since 2002, from 677 to 398 (see Figure 1.1).

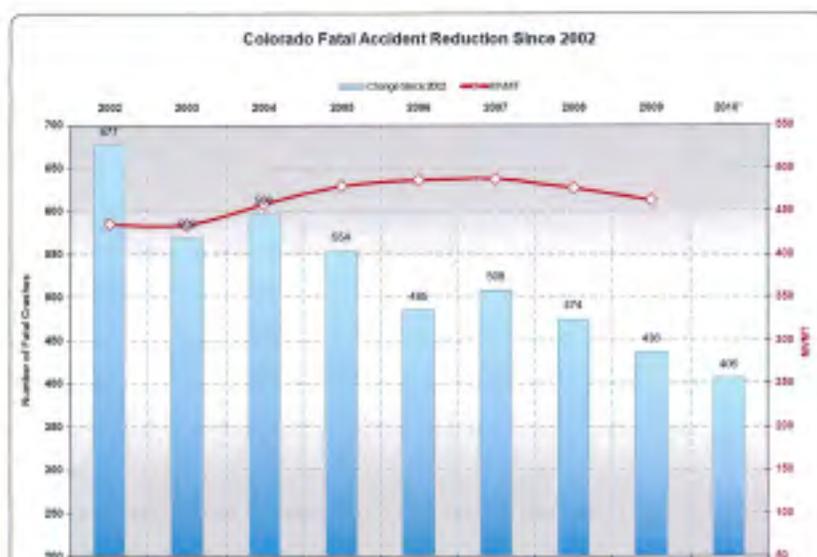


Figure 1.1 Colorado highway fatalities trend

Mendocino County, California

Mendocino County, a large rural county on the Pacific Coast of California, is 100 miles north of San Francisco. It has 3510 square miles and a population of 87,000. It is a mountainous county with a few small inland valleys.

With 1,018 centerline miles of county-maintained roads, Mendocino’s busiest road is a 0.6-mile long four-lane arterial with an ADT of 18,000. Otherwise, about 600 miles are paved two-lane collector and local roadways with ADTs ranging from 200 to 1,000; most of the mileage has ADTs of less than 500. Of the approximately 400 miles of unpaved local roads, some have ADTs of less than 20. Most of the road system is neither flat nor straight, as the county’s longest tangent segment is a mere 2.5 miles.

Washington State

Washington has 83,431 miles of public roads, but Washington State DOT (WSDOT) is responsible for only 7,044 of those miles. It is another rapidly growing state, with a growth rate of 21% over a decade, leading to a current population of 6,660,000. Of all the states on the scan tour, Washington has the highest per capita of licensed drivers at 71%.

Washington's ROR collisions were 42% of the total deaths over a recent three-year period, making ROR the state's most critical priority group.

For WSDOT to achieve its highway safety vision, "Target Zero," the state needs to achieve approximately 23 fewer fatalities and 130 fewer serious injuries each year for the next 20 years. From 2002 through 2008, the state averaged 12 fewer traffic fatalities and 86 fewer serious injuries each year.

Safety Programs and Strategies

SAFETEA-LU established the Highway Safety Improvement Program¹⁶ (HSIP) as a core federal program. An SHSP¹⁷ is a major component and requirement of the HSIP. An SHSP is a statewide coordinated safety plan that provides a comprehensive framework for reducing highway fatalities and serious injuries on all public roads. In a cooperative process, the state DOT develops the SHSP with local, state, federal, and private sector safety stakeholders. The SHSP is a data-driven, four- to five-year comprehensive plan that establishes statewide goals, objectives, and key emphasis areas. The SHSP also integrates the 4 E's of highway safety: engineering, education, enforcement, and emergency medical services (EMS).

The FHWA Safety Web site¹⁸ states that the purpose of an SHSP is to identify the state's key safety needs and guide investment decisions to achieve significant reductions in highway fatalities and serious injuries on all public roads. The SHSP allows all highway safety programs in the state to work together to align and leverage their resources. It also positions the state and its safety partners to address collectively the state's safety challenges on all public roads.

The largest U.S. highway safety problem, roadway-departure crashes, accounts for 53% of all roadway fatalities and 2 million serious injuries each year. Reducing crashes must be held as a high priority for federal, state, and local transportation agencies. Single-vehicle Roadway Departure crashes include ROR crashes, opposite-direction front-to-side crashes, head-on crashes, and sideswipe crashes.

- 39% of all fatalities are single-vehicle ROR crashes
- 20% of all fatalities involve hitting fixed objects (Shielding or removing fixed objects compensates for some driver errors.)
- 68% of road-departure crashes are single-vehicle ROR crashes

Michigan

In Michigan, local agency safety involves two main components. The first, local safety initiatives (LSIs), includes direct traffic engineering services, working with Michigan LTAP to enhance the RoadSoft Safety Module and providing training/mentoring. The second component is local agency programs, with their administration of funds and targets for their lane-departure goals. Typical suggestions for countermeasures from the LSI include tree/fixed-object removal, enhanced curve signing, providing paved shoulders and rumble strips, and slope-flattening or guardrail

¹⁶ Defined in Section 1401 of SAFETEA-LU; FHWA Safety State Highway Improvement Program, <http://safety.fhwa.dot.gov/hsip/>

¹⁷ Strategic Highway Safety Plans, <http://safety.fhwa.dot.gov/safetealu/shspquick.cfm>

¹⁸ FHWA Safety Program, <http://safety.fhwa.dot.gov/>

improvements.

Pennsylvania

The safety of all motorists traveling Pennsylvania's highways is a top priority for PennDOT, and its goal is to save at least 100 additional lives over the preceding year. The agency is working toward this goal by investing millions of dollars in state and federal funding in infrastructure improvements, educational programs, and coordinated law-enforcement campaigns.

Pennsylvania uses what it refers to as the “plan, do, check, act” model in developing, implementing, tracking progress, and re-evaluating its SHSP. For its 2009 update to the SHSP, PennDOT developed specific task-measurement dials that make it easy to track its progress toward its goals and report that progress to the agency leaders at the quarterly Multi-Agency Safety Team (MAST) meeting.

The SHSP partners and stakeholders are brought together annually to review strategies and progress made towards the goals of the plan and to continually renew and enhance the SHSP. Shared ownership is achieved by holding local safety summits in each of the 11 PennDOT Engineering Districts. The results are a safety plan for each district that directly supports the SHSP and involves the local partner and stakeholder organizations.

The PennDOT safety program, which focuses on infrastructure improvements as one of the SHSP's seven safety focus areas, is meant to:

- Reduce head-on and cross-median crashes
- Reduce ROR crashes
- Reduce the severity and frequency of fixed-object crashes
- Address curves
- Reduce intersection crashes

To reduce highway fatalities, PennDOT has developed a comprehensive low-cost SHSP. The state has implemented over 14,500 low-cost safety improvements since 2000, including lane-departure countermeasures of shoulder and CLRS. Most lane-departure countermeasures showed a decrease in crash rates, ranging from 35 to 50% fewer crashes, successfully demonstrating that the countermeasures did affect the crash types for which they were installed.

South Carolina

The fatality rate on South Carolina's rural secondary roads was triple that of the interstates when SCDOT developed the Crash Reduction by Improving Safety on Secondaries (CRISOS) program in 2003. The CRISOS program used low-cost, short-term engineering measures, public education, and stepped up emergency-medical-service and law-enforcement efforts on state-maintained secondary roads with the highest crash rates. Results from six CRISOS-completed roads showed a 48% decrease in fatalities and a 17% drop in injuries.

SCDOT updated CRISOS by developing a new state-funded rural road safety program. The program's goal is to improve safety on rural two-lane roads by reducing the number of crashes, injuries, and fatalities through the implementation of low-cost, short-term engineering strategies. Project selection for this program begins with crash research and analysis of all two-lane rural roads, including primary routes, to determine which roads have a statistically higher-than-average crash rate and/or severity rate. These studies identify all appropriate countermeasures and determine the feasibility of implementing the proposed improvements.¹⁹

Georgia

One-quarter of all fatalities in Georgia result from vehicles leaving the road and hitting a fixed object or overturning. Although it is important to develop methods to keep vehicles from leaving the roadway, it is also important to try to minimize the impact for those that inevitably do. By effectively reducing the consequences of leaving the roadway, a reduction in serious injuries and fatalities would likely follow. Leaving the roadway in rural areas is especially deadly, as two-thirds of fatalities registered in rural settings result from this type of event. In addition to keeping vehicles on the roadway, it is important to reduce the opportunity for vehicles to overturn or strike fixed objects when they stray and minimize injuries when they crash into a fixed object.

GDOT's key traffic safety goals for 2010 were to decrease:

- Traffic fatalities 5% percent, from a 2008 base year average of 1,493 to 1,418
- Serious traffic injuries 1%, from the 2008 average of 115,737 to 114,580
- Fatalities per VMT 0.06%, from the 2007 rate of 1.46 to 1.4

Program initiatives related to lane-departure emphasis areas are:

- Crash impact attenuator upgrade
- Cable barrier systems
- Utility relocation incentives
- Vegetation removal; enhanced recovery areas
- Corridor improvements
- Guardrail and guardrail delineation
- Bridge guardrail
- Guardrail elimination
- Safety edge

Although many Georgia counties do not have engineers, GDOT does offer the entities road safety

¹⁹ South Carolina DOT, State [Maintenance] Program, FY2011

audits and other assistance so that the counties are able to apply for safety funds. Each GDOT district has an off-system coordinator to administer the program.

GDOT's local agency off-system Program allocates \$7 million in state funding for off-system safety improvements, with no matching funds needed by the local agencies. The state reports that 95% of off-system projects are limited to low-cost signing, striping, and installing raised pavement markers.

Minnesota

The Minnesota SHSP²⁰ identified addressing single-vehicle road departure crashes as one of the state's safety emphasis areas. Because they constitute more than 50% of the state's highway fatalities, lane departure, ROR, and head-on crashes are identified as critical emphasis areas.

Historically, safety funds were spent on trunk highways and not local roads. The HSIP program led the Minnesota DOT (MnDOT) to determine where to focus safety funds since black spots are infrequent on local roads and serious crash types are random on local roads.

MnDOT overhauled its safety project development process from a reactive approach to a proactive, systemic one where the lack of crashes on a segment does not indicate a lack of risk. It decided to identify risk factors, or "surrogates," as indicators of potential risk (e.g., for segments, the traffic volume, rate, or density of ROR crashes, sharp curves, pavement edge risk, and access density).

Low-cost systemic safety improvements represent a shift in focus from total crash to fatal and serious-injury crashes, and from higher cost site-specific projects to lower cost systemic projects, with a focus on lane departure. Safety strategies that are important to MnDOT are low-cost, systemic, proactive and reactive strategies that affect lane departure and intersection crashes. Enhanced edge lines, rumble strips and stripes, rural intersection lighting, and curve delineation were the first strategies MnDOT implemented because they are low-cost and could be deployed on many miles of Minnesota's roads in a short amount of time.

MnDOT prioritized the roadway network by utilizing a risk assessment that takes into consideration crash types and crash contributors. The agency provides each county with a risk assessment of its roadway network and a listing of recommended low-cost strategies for specific at-risk roads within the jurisdiction.

Minnesota is currently developing a county road safety plan (CRSP) for each of its 87 counties.²¹ This process uses crash trends and surrogates (risk factors) to identify locations with the highest potential for improvement, particularly rural areas where crash frequency is low. A CRSP concentrates on information associated with the county roadway network and identifies opportunities to reduce the number of fatal and serious-injury crashes. The primary objective of a CRSP is to identify a specific set of low-cost, systemic safety projects that are linked directly to the

²⁰ Minnesota Strategic Highway Safety Plan, <http://www.dot.state.mn.us/trafficeng/safety/shsp/index.html>

²¹ State Aid for Local Transportation, http://www.dot.state.mn.us/stateaid/sa_county_traffic_safety_plans.html

causation factors associated with the most severe crashes on a county's system of highways.

The CRSP summarizes infrastructure safety projects with an implementation base cost ranging from \$2 million to \$5 million on local HSIP targets. Projects may include, but are not limited to, such countermeasures as enhanced intersection signing, pavement markings, and curve delineation and dynamic warning devices.

Wright County, Minnesota

The county identified lane-departure crashes as the main critical emphasis area and has already undertaken many initiatives (e.g., safety edge, chevrons, rumble stripes, pavement marking options, dynamic signing, intersection lighting, and "distance dots").

Wright County focuses on both high-crash locations (reactive) and system-wide projects (proactive). Following the state's lead, it has allotted 70% of funding to proactive projects and 30% to reactive measures.

Iowa

Iowa identified lane-departure crashes as a critical emphasis area and included it in Iowa's Comprehensive Highway Safety Plan²², and specifically in the state's 5% Transparency Report. In addition to the legislative strategies, preventing lane departures, making low-cost improvements, and intersection safety is important to Iowa.

"One death is one too many."

~Iowa DOT SHSP

At one time, Iowa's strategies were reactive, primarily focusing on "high crash" locations. However, the state has been moving toward proactive strategies (e.g., median cable, curve signing, paving shoulders, shoulder and CLRS, and safety edge). Approximately 25% of the work is proactive, not including the proactive initiatives that have become standard practice.

Some lane-departure strategies (i.e., curve improvements, intersection improvements, and cable median) are being targeted based on crash history. Some have become standard practice (i.e., safety edge, paved shoulders, and shoulder and CLRS).

Local transportation agencies do not have their own safety plans; however, both municipal and county groups are identifying strategies from their own resources. Some of the lane-departure strategies being implemented at the local level are curve signing, shoulder widening/paving, safety edge, and rumble stripes.

Iowa's cities and counties that do not have a staff traffic engineer are eligible to request technical assistance from the state DOT. The Iowa Traffic Engineering Assistance Program (TEAP) will fund up to 100 hours of traffic engineering expertise to local government agencies. The purpose is to identify cost-effective traffic safety and operational improvements, as well as potential funding

²² Iowa Comprehensive Highway Safety Plan, <http://www.iowadot.gov/traffic/chsp/index.htm>

sources to implement the recommendations. Typical studies include high-crash locations, unique lane configurations, obsolete traffic control devices, school pedestrians, truck routes, and parking issues.

According to the Iowa DOT Office of Traffic Safety, the TEAP's statewide annual funding level is \$125,000, with no local match requirement. However, the applicant is required to assist the consultant with data collection (e.g., as-built plans, traffic counts, street maps, and crash reports), if needed.²³

Colorado

CDOT has also identified lane departure as a critical emphasis area in its Highway Safety Plan. CDOT's strategy is to focus on both on "high crash" locations (reactive) and to evaluate system-wide issues (proactive), but funds reactive locations at 90%, and proactive locations at 10%.

The agency manages safety through its centralized Safety Assessment Program. Safety assessments are available for the entire system and are done on every project at scoping.

A Statement of Philosophy

The efficient and responsible investment of resources in addressing safety problems is a difficult task. Since crashes occur on all highways in use, it is inappropriate to say of any highway that it is safe. However, it is correct to say that highways can be built to be safer or less safe. Road safety is a matter of degree. When making decisions affecting road safety it is critical to understand that expenditure of limited available funds on improvements in places where it prevents few injuries and saves few lives can mean that injuries will occur and lives will be lost by not spending them in places where more crashes could have been prevented. It is CDOT's objective to maximize crash reduction within the limitations of available budgets by making road safety improvements at locations where it does the most good or prevents the most crashes.

The safety performance function (SPF) is used to assess the magnitude of safety problems on highway segments that will be resurfaced. The SPF reflects a relationship between ADT and the number of crashes for a roadway segment.

CDOT developed a concept called Level of Service of Safety (LOSS) to reflect a roadway segment's performance regarding its expected crash frequency and severity at a specific level of average ADT. LOSS only provides a crash frequency and severity comparison with the expected norm; it does not, however, provide any information related to the nature of the safety problem itself. If a safety problem is present, LOSS will only describe its magnitude. The nature of the problem is determined through diagnostic analysis using direct diagnostics, pattern recognition techniques, crash diagramming in concert with site visits, and plan reviews. In the course of in-depth project-level safety studies of hundreds of locations, a comprehensive methodology was

²³ Iowa Traffic Engineering Assistance Program (TEAP), www.iowadot.gov/traffic/teap.html

developed to conduct diagnostic analyses of safety problems for different classes of roads in various environments.²⁴

Strategies to address the locations with the greatest potential for crash reduction are implemented first. Partnerships with local agencies help spread the money and allow more locations to be addressed, thus providing the greatest benefit for crash reduction with limited funds. For safety planning emphasis, rural areas are treated the same as urban areas; however, funding is directed towards problem locations.

A reduction in the number of fatal crashes is proof that CDOT is making progress with the initiatives identified in the safety plan (e.g., addressing lane departures and mitigating head-on crashes).

Mendocino County, California

A local agency can start small to make its efforts manageable, and then build on its successes over time. For example, the Road System Traffic Safety Review (TSR) program²⁵ is a highly beneficial program for Mendocino County. TSRs are a systemic way of identifying and treating collision generators. They address problems unique to a local transportation agency or to low-volume roadways and stretch resources. Local roadways have several interrelated problems, such as physical deficiencies, a lack of statistically relevant crash data, and (usually) poor safety records. With their limited resources, it is difficult for local agencies to obtain state funding, especially with their limited tax base and political clout.

During the 1990s, the Mendocino County DOT started the TSR program as a low-cost effort to identify and treat collision generators systemically. This effort allows the county to stretch its resources to maximum limits while improving signing and markings on the arterials and collectors in the system.

TSRs work by treating road conditions that contribute to crashes. The key is to look for and treat the generators throughout the system. The best place to start is to systemically upgrade signing and markings, as these are cost-effective, easy to implement (no environmental impact statement, permits, or outside reviews are needed).

The county measured the program's effectiveness by comparing crash data for the reviewed roads with data for roads not included in, or influenced by, the reviews. It selected two sets of control roads: county-maintained roads not reviewed and state highways within the county. Over two consecutive three-year review cycles, the number of crashes on the reviewed roads fell by 42%, while on the county-maintained roads that were not reviewed, they increased by 26%. On the state highways, crashes fell by 3%.

²⁴ Safety-Conscious Planning Corridor Level Application and a Review of the Case History, Jake Kononov, PhD, PE, Colorado DOT

²⁵ Signing and Marking Improvements: Mendocino County, California in Roadway Departure Safety: A Manual for Local Rural Road Owners, http://safety.fhwa.dot.gov/local_rural/training/fhwasa1109/sec_6.cfm

The total cost to conduct the reviews and implement the recommended changes was less than \$80,000. Since the 1990s, Mendocino County has expanded its Road System TSR program to cover its entire maintained road system.²⁶

Washington State

Washington State DOT (WSDOT) has determined that two-thirds of all crashes on the local system are ROR and has identified prioritized sections for targeted safety projects. WSDOT has involved local agencies in safety. To help the counties' efforts, the state agency has mapped all local roads and can provide detailed crash analysis for each of the state's 39 counties.

The state's HSIG is a coordinated and proactive roadway safety approach that employs a team of safety experts, advocates, and executives, which facilitates buy-in from all agency regions and programs on funding priorities and implementation of safety policy. The HSIG's multidisciplinary approach has played a vital role in Washington State besting the national milestone with the lowest fatality rate in state history: 0.94 fatalities per 100 million vehicle miles traveled.

The HSIG was instrumental in WSDOT providing greater resources and emphasis on safety by instituting CLRS, cable median barrier (CMB), and low-cost safety-enhancement programs. These programs contributed to the decrease in fatal and serious injury collisions.²⁷

WSDOT's Low-Cost Enhancement program is designed to allow the state to deliver lower-cost projects that provide immediate, sometimes interim or sometimes long-term safety improvements to the highway system. Minor operational and enhancement project types include the following:

- Driver guidance projects (warning signs, lighting and supplemental illumination, and supplemental delineation)
- Pavement widening projects (widen shoulders)
- Rechannelize lanes on pavement projects (through use of pavement markings)

Low-cost projects also include modifications to roadside features for safety purposes, such as addressing clear zone hazards or sight distance concerns (e.g., slope flattening, recontouring a ditch, closing a ditch with culvert, removing a hazard, or adding roadside safety devices).

²⁶ "Evaluation of a Low-Cost Program of Road System Traffic Safety Review for County Highways," Stephen H. Ford and Eugene C. Calvert, *Transportation Research Record*, Vol. 1819A, 2003

²⁷ National Roadway Safety Awards, 2009 – Best Practices; Winner – Program Planning, Development & Evaluation, Highway Safety Issues Group, FHWA

Lane-Departure Countermeasures

Introduction

AASHTO's SHSP serves as a sample plan and is a guideline for states to emulate. AASHTO suggests addressing three elements that are directly related to this scan:

- Keeping vehicles on the roadway
- Minimizing the consequences of vehicles leaving the road
- Reducing head-on and across-median crashes

Every state has its own SHSP tailored to its own particular needs and goals to mitigate these elements.

Successful agencies addressed not only “hot” or “black” spots in identifying crash locations (i.e., reactive), but they also realized that being proactive is an effective use of funding. Proactive countermeasures work well with systemic treatments for proven countermeasures. Some agencies were active in applying promising and innovative countermeasures at problematic spot locations.

The scan team focused on these relatively low-cost initiatives taken by transportation agencies to mitigate the causes and effects of lane departures:

- Shoulder rumble strips (SRS)
- Centerline Rumble Strips (CLRS)
- Edge line rumble stripes (ELRS)
- Safety edge and pavement drop-offs
- Paved shoulder widening
- Edge line pavement markings (width and composition)
- In-pavement markings at curves, (e.g., transverse markings and speed advisories)
- Additional signing, especially at horizontal curves (including chevrons and advisory speed limits)
- Dynamic signing (e.g., speed feedback and LED illuminated signs)
- Cable median barrier (CMB)
- Rural traffic calming
- Horizontal curve treatments
- Remove Fixed-object hazards

Pennsylvania

PennDOT's strategies for addressing lane-departure crashes concentrate on high crash locations and systemic issues. The systemic issues (i.e., CLRSs, ELRSs, and curve-related improvements) account for approximately 40% of system-wide issues. The countermeasures showing the greatest impacts in reducing lane-departure crashes were CLRSs, improved horizontal curve delineation and advanced curve warning markings, and utility pole relocation.²⁸

Minnesota

MnDOT lists CMB, rumble strips, and rumble stripes as the countermeasures it considers successful (although the state needs to do more evaluations).

Iowa

Iowa DOT has identified safety edge and curve signing as low-cost measures. The DOT is not sure of the results (i.e., benefit-cost ratio) of narrow edge line rumble stripes, safety edge, or CLRS. However, it has mentioned that deterioration of rumble strips caused by snowplows is a problem.

Colorado

In Colorado, 80% of the lane-departure crashes occur on the state's on-road system and 20% on the off-road system. CDOT uses a variety of tools (e.g., crash data, agency input, tried practices, countermeasures, and handbooks) when it is considering using a particular treatment.

- Successful countermeasures – CMB, better shoulders, rumble strips, striping, signing, and technology
- Unsuccessful countermeasures – nighttime speed reductions and static wildlife signs (Colorado believes that they failed because initial studies before installation did not show a pattern related to the proposed fix; however, the countermeasures were installed anyway.)
- As-yet-unknown outcome (i.e., benefit-cost ratio) – high-friction course overlay, some traffic-calming techniques, red-light cameras, flashing left-turn phase, wildlife detection zones, and safety edge

²⁸ The Impact of Transportation Research A Sampler of High-Value Research; Evaluation of the Effectiveness of PennDOT's Low Cost Safety Improvement Program; AASHTO Research Advisory Committee – Region 1, 2009

Rumble Strips and Rumble Stripes



Figure 3.1 Examples of CLRS (left) and SRS (right)

Michigan

MDOT has an aggressive Non-Freeway Rumble Strip Program with approximately 1,700 lane miles (2,700 shoulder miles) of SRSs and 5,400 miles of CLRS. Locations chosen in this system-wide initiative are long sections of road and are just not on “the bad curves” (proactive) because these types of crash location are random, but the crash type is not.

MDOT’s “Claim to Fame” is retrofitting. It has installed rumble strips on all sorts of pavements, with no premature failures reported to date:

- CLRS over chip seal, chip seal over CLRS
- Rumble strip over crack seal, crack seal over rumble strip
- Rumble strip over microsurface, micro surface over rumble strip

Rumble strips have been used successfully on all pavement conditions. Although MDOT has received some concerns about maintenance, motorcycles, and noise, it believes that rumble strips are an effective tool to address lane-departure crashes.

Many agencies ask, “Will rumble strips cause premature pavement failure?” Michigan’s rule of thumb is- “mill on good pavement—pavement still good; mill on bad pavement—pavement still bad”.²⁹

A national crash-reduction study indicated that after installation of CLRS (and some SRS) on rural two- and four-lane highways, MDOT can project an annual reduction of more than 300 crashes, approximately 60 incapacitating injuries, and the saving of more than 15 lives.³⁰

²⁹ Michigan DOT: Non-Freeway Rumble Strips, presentation to the NCHRP 20-68A Domestic Scan Team: 09-03; Jill Morena, P.E. Lynnette Firman, P.E. November 15, 2010

³⁰ Centerline Rumble Strips Are Busy Saving Lives, <http://www.michigan.gov/mdot/0,4616,7-151-9615-191394--,00.html>

Pennsylvania

PennDOT lane-departure countermeasures are reported to include 4405 miles of CLRS, which are placed only in no-passing zones. The number of fatalities in head-on collisions has declined by nearly 40% since 2000 due to the installation of more than 3500 miles of CLRS; the annual average of 180 over the last five years to 175 in 2010. Additionally, the state has installed 3652 miles of SRS/ELRS, and ROR fatalities have fallen from 703 over the last five years to 665 in 2010.

Pennsylvania believes that rumble strips should be installed in pavement less than two years old to prevent premature pavement failure. Rumble strips should only be installed at locations that are three to five years old, with no existing hairline cracks. If rumble strips are installed at locations with pavement older than two years, districts should study the pavement after installation and report pavement failure to the central office. These locations are analyzed by comparing the density of the crack at the rumble strip locations with cracks in adjacent pavement without rumble strips.

Noise on rumble strips and bicyclists riding on SRS are challenges facing PennDOT. Bicycling groups in the state (as in many of the states the scan team visited) have concerns about their use. Pennsylvania has reached out to the cycling community to gather wider support.

South Carolina

In South Carolina, rumble strips have proven to be one of the most cost-effective ways of reducing ROR crashes—they can reduce these crashes by up to 80%. For the most part, SCDOT uses profile thermoplastic pavement markings instead of the milled rumble strip. Most of the state does not get any snow accumulation, so these raised markings are not affected by snowplows.

The state has already installed rumble strips on four-lane divided highways and on secondary and primary highways across the state. Rumble strip will be installed on 600 miles of interstate and 1000 miles of primary routes. A total of 822 miles of profile thermoplastic edge line markings will be used.³¹

SCDOT faces the dual challenges of the negative public perception of noise generating from rumble strips and developing a trusting, working relationship with bicycling groups.

Georgia

GDOT has a systemic approach to rumble strip installation as part of yearly resurfacing projects, using crash data to determine locations. It also installs CLRS, but avoids using SRS and CLRS in the same location.

Minnesota

MnDOT is currently developing policies and technical memoranda that will require the

³¹ SCDOT Launches Highway Safety Campaign Aimed at Reducing Run-off-Road Crashes, Fatalities, http://www.scdot.org/ArtMan/publish/article_901.shtml

implementation of CLRS, ELRS (and edge line stripes), and the safety edge on local county and state trunk highways.

Since 2007, MnDOT's HSIP program has funded:

- Over 6500 miles of six-inch-wide edge lines
- 80 miles of ELRS
- Almost 600 miles of edge-line rumble stripes
- Over 230 rural intersections with street lighting
- Over 1300 curves with chevron signing

To address the concerns of bicycling groups, the state uses a pattern that provides gaps every 50 feet. Additionally, the agency tries to maintain a reasonable paved shoulder width for cycling use. Excessive noise complaints after the installation of ELRS are ongoing problems, and MnDOT has not totally overcome this issue. Jurisdictions are reluctant to install this countermeasure in many locations. The agency is working to develop better guidelines for installation to minimize the impacts.

Wright County, Minnesota

One countermeasure that was not initially as successful in Wright County was the installation of rumble stripes. These were installed on four different roadways, totaling about 20 centerline miles. Noise was a major problem for a roadway with about 10,000 ADT and 10-foot paved shoulders. Even though the rumble stripes were placed 13 feet from the centerline, residents along the roadway made many complaints.

The agency attempted to deaden the sound in a few locations by filling in with an oil-emulsion material, but it was not very helpful. This became a very controversial political issue that made the headlines of the local newspaper.

The solution, which proved very successful, was to add a six-inch wide strip at the normal 12-foot mark along the roadway. This solved the problem. In the county's view, drivers drifted to wherever the edge line was, and the 10-foot paved shoulder provided more opportunity for wandering.

The County will be using rumble strips in the future on their 8-10 foot paved shoulders.

Iowa

In Iowa, single-vehicle ROR crashes are the most common crash type on rural two-lane roads. Rumble strips have proven effective in mitigating these crashes; however, these strips are commonly installed in paved shoulders adjacent to higher-volume state highways. Lane edge rumble stripes³² may be an effective, relatively low-cost method that can be used to reduce the

³² Lane edge rumble stripes are a combination of conventional rumble strips with a painted edge line placed on the surface of the milled area.

number of ROR crashes on local-agency-owned lower-volume paved rural roads, which generally do not have paved shoulders. Rumble strips are used in locations without a shoulder or only a very narrow paved shoulder and consists of a four- to six-inch rumble stripes. The results were found to be in locations where there were offsets between strips and pavement edge.

A CTRE study of six locations found that rumble stripes were a beneficial low-cost tool for counties to address lane-departure concerns. Stripes that were between four and six inches wide were installed in both asphalt and concrete pavement in the traveled lanes on 22- and 24-foot pavements, and in paved shoulders on wider pavements (see Figure 3.2).

- | |
|---|
| <ul style="list-style-type: none"> ■ In general, the wear of the paint markings in the rumble stripes' grooves was similar to the wear on regular surfaces. The rumble stripes did not appear to improve the longevity of the painted edge line. |
| <ul style="list-style-type: none"> ■ The milling machine became unstable and tipped on the low side of elevated horizontal curves because of its high center of gravity. Milling on curves was suspended until the machine was modified. |
| <ul style="list-style-type: none"> ■ Millings had to be blown out with an air compressor before edge lines could be applied. |
| <ul style="list-style-type: none"> ■ There was not enough downward pressure on the milling head, so it was difficult to mill portland cement concrete to the desired depth. |
| <ul style="list-style-type: none"> ■ Milling had to be omitted in areas near mailboxes to avoid damage. |
| <ul style="list-style-type: none"> ■ Aligning the painted edge line with the rumble strip was difficult but necessary for maximum effectiveness. |
| <ul style="list-style-type: none"> ■ In some areas, debris collected in the grooved part of the rumble strip and reduced visibility of the painted edge line. |
| <ul style="list-style-type: none"> ■ Preliminary results showed that the number of vehicles within one and two feet of the lane edge decreased by approximately 2% and 7%, respectively. |
| <ul style="list-style-type: none"> ■ The public and special user groups, including the Amish and bicyclists, had few complaints about the rumble stripes. |

Figure 3.2 Iowa State University/Center for Transportation Research and Education rumble stripes findings³³

Iowa DOT has used centerline, shoulder, or ELRS on two-lane rural roads. The agency accommodates bicyclists' concerns by providing at least two feet of pavement shoulder outside of the strip.

The new standards for milled rumble strips³⁴ were developed using NCHRP Report 641³⁵ as a reference and are used in both hot mix asphalt and portland cement concrete (PCC) pavements. In

³³ "Evaluation of Rumble Stripes on Low-Volume Rural Roads in Iowa—Phase I," Key Findings, Tech Transfer Summary, Midwest Research Consortium, CTRE Iowa State University

³⁴ Milled Rumble Strips, <http://www.iowadot.gov/design/dmanual/03c-05.pdf>

³⁵ NCHRP Report 641, Guidance for the Design and Application of Shoulder and Centerline Rumble Strips, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_641.pdf

Iowa, a project qualifies for milled CLRS if it is a two-lane primary road with current ADT greater than 3,000 and two-foot or wider shoulders with at least an 11-foot lane width, or at high crash corridors, under certain conditions.

Milled SRSs are also provided on PCC roadways having 14-foot-wide lanes (on pavements not having concrete shoulders). On highways where bicyclists are allowed, a gap pattern is provided in the milled SRS (48 feet on, 12 feet off).

Colorado

CDOT installs rumble strips on all rural interstate highways as a lane-departure countermeasure and uses them (i.e., centerline, shoulder, or edge line) on two-lane rural roads. Research done with bicyclists to determine the depth and cycle of the rumble strip resulted in new policy as CDOT Standard M-614-1³⁶.

Washington State

WSDOT's rumble strip program began in 1999. The policy states that SRSs are not required on undivided highways but may be used when ROR experience is high. SRSs are placed on rural roads with posted speeds over 45 mph and if four feet or more of paved shoulder remains.

In 2004 WSDOT determined that there were more than 500 cross-centerline collisions each year, with 40 of them being fatal or serious-injury crashes. CLRSs are specified when engineering analysis indicates that cross-centerline crashes are correctible with CLRSs. This action resulted in a 49% reduction in the rate of fatal and serious-injury cross-centerline collisions.

Missouri

The Missouri DOT (MoDOT) has implemented policy stating that all major roads will have improved shoulders (minimum of 4 feet) and edge-line rumble stripes. Additionally, these heavily traveled roads will also have centerline rumble stripes on the two-lane facilities. Since 2005, when this policy went into force, MoDOT has seen a 40% reduction in lane-departure fatalities on these roads. Once all major roads are complete, 5600 centerline miles of roadway will have these life-saving strategies installed.

MoDOT has painted the rumble strip due to advantages during adverse travel. For instance, when it is dark and raining, the rumble stripe will still provide the driver with a visible line (the line often tends to washout on a flat surface).

³⁶ Rumble Strips M-614-1 All,

<http://www.coloradodot.info/business/designsupport/standard-plans/2006-m-standards/2006-m-standards-pdfs/46-rumble-strips/rumble-strips-m-614-1-all.pdf/view>

Drop-Offs, Safety Edge, and Shoulder Widening

Pennsylvania

PennDOT eliminates high-severity shoulder drop-offs through its maintenance program. It has also adopted the safety edge. The agency accommodated bicyclists' concerns about the use of SRSs by providing a minimum four-foot riding shoulder and, at spot locations, it will widen lanes on curves.

South Carolina

In South Carolina, a two-foot paved widening of the shoulder is now the standard for roadways that previously did not have a paved shoulder. Approximately 1,000 miles have been added so far.

In addition, the agency has updated its enhancement program to allow the improvement of bicycle facilities on some roads by increasing the paved shoulder widths from two to four feet. SCDOT will consider paving four-foot shoulders on highways designated as part of South Carolina's six cross-state Bicycle Tour Routes when those roads are scheduled for resurfacing. Up to \$1.5 million is provided annually to fund the paving of the additional pavement width.³⁷

Georgia

GDOT is a national leader in the use of a pavement safety edge. Because concerns about the constructability of the safety edge are widespread, GDOT constructed a 13-mile pavement with a redesigned paver's edge shoe. It made improvements, including changing from a 45-degree to a safer 30-degree angle and improving the compaction of the pavement edge by adding springs and redesigning the shoe with a radius so that the asphalt would be extruded. The pavement built with the safety edge not only provided the safer shape, but it also showed less sign of cracking than the section built using conventional techniques. GDOT has put this shape into practice on paving projects throughout the state.

Minnesota

In Minnesota, a safety edge policy was under development. Implementation was scheduled for July 2011.

Wright County, Minnesota

Wright County has adopted the safety edge as standard procedure for all overlay projects that do not have paved shoulders. However, during the 2010 construction season, the contractor had problems and was not able to build the proper angle from the paver's end shoe.

Iowa

In Iowa, a study for the AAA Foundation for Traffic Safety at 230 locations (in two states) looked at pavement edge drop-offs. According to the study, the FHWA estimates that each year 11,000

³⁷ SCDOT Enhancement Program Includes Widening Shoulders for Bicyclists, http://www.scdot.org/ArtMan/publish/article_1062.shtml

injuries and 160 fatalities are related to drop-offs. The study concluded that while these make up small numbers of crashes, they are more likely to be severe. Even though they are small, these numbers are still large enough to warrant attention and treatment. The research showed that the two-inch depth threshold used by many states seems justified, and most agencies have a procedure for addressing drop-offs through their maintenance program.

Iowa DOT standard for the safety edge calls for it to be installed on new construction or rehabbed pavement on all primary highway unless the roadway or shoulder is curbed or if the paved shoulder width is four feet or greater. The safety edge will be beveled to a 30-degree angle, not including the surface slope. On PCC, the construction will add one foot of width to the pavement and a six-inch-deep slope portion (see Figure 3.3).



Figure 3.3 *Iowa safety edge on PCC*

One beneficial outcome of the safety edge standard is that contractors have shown a desire to utilize the safety edge on their own to improve their construction sequence and meet maintenance-of-traffic requirements.

Colorado

CDOT is working toward making the safety edge a part of its typical cross-section for all projects.

Missouri

MoDOT has implemented an initiative to install the safety edge on at least one paving project during the 2011 construction. This approach will allow contractors and MoDOT personnel (as well as locals) to observe the constructability of the safety edge. Once information is gleaned from this opportunity, the best practices will be provided to all and a policy will be in place.

Additionally, MoDOT has installed numerous two-foot shoulder improvement projects on some of the state's most traveled roads that have a safety need; these are lower order than the major roads (i.e., minor arterials and lower). The agency is also installing an edge-line rumble stripe on these projects.

Pavement Markings, Signage, and Delineation

Pavement Markings

South Carolina uses dashed edge lines traversing through intersections, which act as guidelines for drivers on the through-road. MnDOT uses wider six-inch pavement markings and wet reflective markings as standard markings.

MoDOT has implemented in policy that all major roads (i.e., principal arterial and higher order) will receive a six-inch stripe. The only time this will not hold true is the centerline for the two-lane major roads. Additionally, MoDOT is painting the edge line stripe on routes that have traffic as low as 400 ADT. All routes require a centerline stripe.

Signage

Michigan

MDOT's Traffic Signing Program is a statewide program to upgrade signs utilizing a 15-year replacement cycle goal. It is intended to improve the visibility of signs along corridors and update sign legends, locations, and support structures. This program has a budget of \$14 million.

MDOT standards call for fluorescent yellow warning signs (Type IX), ASTM³⁸ Type IV regulatory signs, ASTM Type IX on Type IX guide signs. Clearview font is now the standard font on all guide signs (see Figure 3.4).



Figure 3.4 Michigan traffic signing program

The revised standard results in a 65% increase in reflectivity, increased daytime visibility (from 3 to 1), and an overall improved warning sign system for the target audience. Research shows that changing the font to Clearview provides a 27% increase in nighttime visibility.³⁹

For improved emergency response times, Michigan has also installed Enhanced Reference

³⁸ American Society of Testing and Materials

³⁹ New Lettering for Signs, http://www.michigan.gov/mdot/0,1607,7-151-9621_11041_32687-100477--,00.html

Location Signs at 1 mile rural spacing and 0.2 mile on urban freeways.

Mendocino County, California

Once it performs its TSR and determines the collision generators for a road segment, the agency's goal is to locate similar locations throughout its road system since these types of crashes may be occurring elsewhere on the system. Mendocino County usually accomplishes this by making simple fixes (e.g., signage, delineation, and/or markings).

Wright County, Minnesota

Wright County is in the process of experimenting with two dynamic signing programs. One is an intersection warning system, and the other is a dynamic curve-warning chevron installation. Both installations use off-the-shelf products. County officials pointed out to the team that they do not have a problem with vandalism of the signs or their associated electronic boxes.

Rural intersection lighting was one of the first strategies Wright County implemented. This was based on a number of factors, including the benefit-cost ratios, traffic volumes, and crashes. Lighting has been very successful based on the many positive comments from the public and highway maintenance personnel.

Iowa

An Iowa study focused on dynamic speed feedback signs that activate a message only to “problem” drivers (i.e., those who are traveling over a set speed threshold). The results are not yet available, but indications are that the signs have been overall successful in reducing speeds. One negative to this countermeasure, as reported by Iowa DOT, is a vandalism problem.

Colorado

CDOT has installed an advanced curve-warning system comprising speed-activated LED imbedded curve warning signs (W1-11s with several W1-8s) at one mountain location with five hairpin-type curves. Good results have been achieved so far, but more data is needed.

Delineation

Michigan has a test program in place for continuous line delineation on guardrail and barriers using proprietary products. Results so far are promising, and the agency believes that there is value in delineation: drivers will see delineation on guardrail and median guard cable on the major roads.

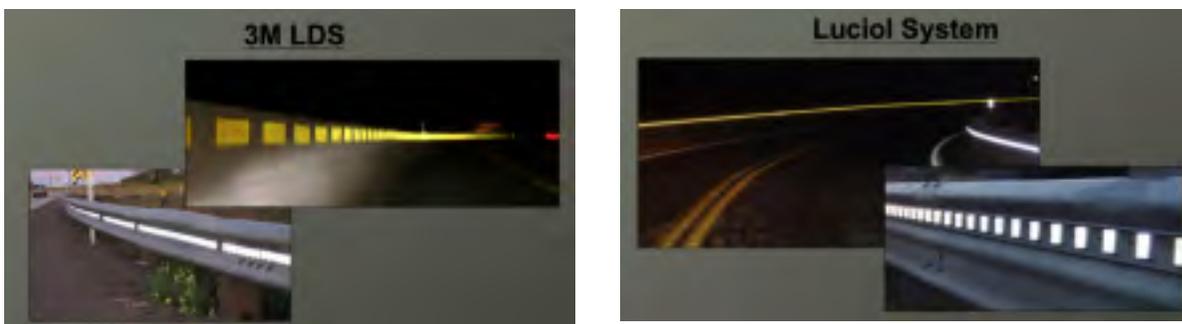


Figure 3.5 *Proprietary delineation products*

Horizontal Curve Treatments and High-Friction Pavement

According to NCHRP Report 500⁴⁰, 25% of fatal crashes occur on horizontal curves.

Pennsylvania

PennDOT adds enhanced signage, markings, and delineation on sharp curves, as needed.

Georgia

GDOT is developing a program to address priority curves with high-friction pavement and/or warning signs and chevrons.

Minnesota

Road-departure crashes are one of the safety emphasis areas of MnDOT's SHSP. These crashes are overrepresented on horizontal curves; however, not all curves need a safety investment, and the presence of crashes is not a good indicator of relative risk.

Minnesota sought for a systemic approach to identifying at-risk curves. The state studied approximately 7200 curves on county roads:

- 80% (5800) had no crash history
- 2160 had a history of severe crashes
- 11 had a history of multiple severe crashes

Crash surrogates (i.e., risk factors) for curves were found to be the ADT range, the radius, a history of severe crashes on the curve, the presence of an intersection on the curve, and if there is a “visual trap.” Statewide, MnDOT identified 15% of its curves as high-priority, at-risk locations. It found that most curve crashes occur on paved roads, with a radius between 500 and 1500 feet, and an ADT between 500 and 1500 vehicles.

Crash rates in curves were found to increase as the radius decreased below 2000 feet. Approximately 90% of fatal crashes and 75% of injury crashes occurred in curves with radii of less than 1500 feet. (Curve radius can be determined inexpensively, for example, by using Google Earth⁴¹.) The characteristics of curves with crashes were identified to be radius, volume, presence of an intersection, visual trap, and proximity to other high-priority curves. These characteristics prioritize curves for safety improvements.⁴²

Countermeasures in horizontal curves include chevrons/delineation, rumble strips, wider markings, and dynamic feedback signs. The state has found that the most effective

⁴⁰ NCHRP Implementation Guides, <http://safety.transportation.org/guides.aspx>

⁴¹ Google Earth, <http://www.google.com/earth/index.html>

⁴² “Horizontal Curves—A New Method for Identifying At-Risk Locations for Safety Investment,” Howard Preston (CH2M HILL, Inc.), 2009 Mid-Continent Transportation Research Symposium, August 2009

Michigan

MDOT knows that cross-median crashes have severe and catastrophic consequences, as fatalities and severe injuries are the norm. The purpose for installing CMB is to reduce the frequency and severity of cross-median crashes in a safe, reliable, and economical manner.

Michigan's CMB program has installed 180 miles so far and is planning to install an additional 100 miles of high-tension cable in freeway medians. Seventy-five percent of cable projects are funded by using HSIP funds as standalone projects, which can be programmed faster than adding the countermeasure to an upcoming project.

Benefits of CMB (specifically high-tension cable barrier) are that it:

- Is highly effective at capturing and redirecting impacting vehicles
- Meets federally-mandated crash testing standards
- Is approximately 95% effective at capturing and redirecting impacting vehicles

MDOT determines CMB as a relatively low-cost solution, as cable barrier is about one-third the cost of steel guardrail and only a quarter of the cost of concrete barrier. The agency will invest more than \$40 million total to install 280 miles of cable statewide in response to a 340-mile median crash analysis:

- Cable barrier is \$12 to \$15 per foot
- Median guardrail is \$28 to \$33 per foot
- Concrete barrier is \$80 and more per foot

Michigan indicates that it is too early to conduct a comprehensive before/after analysis; however, preliminary findings point to a reported increase in property-damage-only crashes. It also reported that no known cross-median fatalities have occurred in areas where cable barrier has been installed.

During fall 2011, researchers will begin an examination of cable barrier installations in Michigan. In addition to considering its effectiveness, researchers will analyze lifecycle costs, location considerations, and the effects of cable barrier on different types of road users (e.g., motorcyclists). The research project will produce guidelines for future cable barrier installations.

Other benefits of using cable barrier are its ease of maintenance, in that it usually remains operative after a typical impact and utilizes features that simplify repairs. It can be installed on slopes that are too steep for other barrier types, where extensive re-grading and expensive drainage structures usually would be required.

The goal of MDOT's cable barrier initiative is to save at least 13 lives and prevent 51 incapacitating injuries per year by using cable barrier.⁴³

⁴³ High-Tension Cable, Carlos Torres, PE, Michigan DOT, presentation to the NCHRP 09-03 domestic scan team, November 15, 2010

Pennsylvania

Pennsylvania has installed more than 100 miles of cable median guiderail statewide since 2005. A completed analysis of 10 locations (30 miles) shows that three years before installation there were 32 crossover crashes in the three years before cable median guiderail was installed. Over the three years after installation, there were only two crossover crashes.

PennDOT has spent \$5 million to install cable and median barrier along interstates. Its data shows a one-year economic savings due to reduction in fatality/injury of \$22,431,163 and a one-year cost-to-benefit ratio of 2.04.

South Carolina

SCDOT has finished a 10-year program to install low-tension CMB on all 400 of the warranted mileage of interstates.

Minnesota

Minnesota's cross-median crashes are three times more deadly than other types of crashes. They are also difficult to solve, as random times, locations, and causes make identifying likely locations difficult. So far, the state has installed 179 miles of high-tension cable and was planning to install another 100 miles by end of 2011.

CMB were placed on opposite side of median of the direction of the majority of lane departure crashes, while placing in accordance with FHWA's National Crash Analysis Center recommendations.

Based on its study results, MnDOT has had no fatalities where CMB is installed, saving an estimated 77 lives to date.

“One life saved for every 17 miles of cable installed.”

~Minnesota DOT

Washington State

In 2001, Washington adopted new guidelines for using a barrier in medians less than 50' in width (regardless of crash history). In addition, WSDOT identified locations, some with medians widths over 50', where cross median crashes were occurred and this list was used to program barrier projects when funding was available. To date, WSDOT has installed 181 miles of cable (41 miles of the original generic low-tension system). There were 1650 cable collisions, a 65% reduction in the rate of cross-median crashes, and a 57% reduction in annual fatal and serious-injury cross-median collisions.

Missouri

MoDOT has installed median guard cable that dates back to the 1980s. However, the system-wide installation approach began in 2002, when Missouri had a history of cross-median crashes, many resulting in severe crashes. MoDOT determined that the only way to virtually eliminate this type of crash was to aggressively install median guard cable. As a result, nearly 640 miles of cable have

been installed to date, and it is estimated that more than 45 lives are saved each year.

On two of the interstates that have median guard cable, cross-median fatalities have gone from highs of nearly 50 a year down to only one or two a year. Internal evaluation of the system has indicated that the system can reduce the chance of vehicles reaching the opposing direction by over 98%.

Rural Traffic Calming

Michigan

Michigan offers “road diets” to qualified and interested rural communities as a form of traffic calming. A road diet reduces the number or width of travel lanes and rededicates the freed space to other uses. The paved curb-to-curb width usually stays intact, but the pavement striping is changed. The most common road diet takes a four-lane undivided highway and redistributes the roadway to one travel lane in each direction, a center turn lane, and may allow for either on-street parking or bike lanes. Not all road-diet locations are necessarily rural.

Michigan is currently studying the performance of road diets in the state. The study data includes information from both local-agency and MDOT conversions, and the study’s deliverables will be applicable to both types of agencies. MDOT suggests that some agencies do conversions through the LSI effort, with local agency programs providing funding for the conversion. Traffic calming effects may or may not be included in the research effort due to availability of before data. At the time this report was written, MDOT’s one-year research effort was at the halfway point.

MDOT has converted 44 corridors having a combined length of 46 miles, and the local agencies have converted 54 corridors, covering a length of 50 miles. MDOT’s road-diet efforts are both for traffic calming and to reduce crashes.

Pennsylvania

In Pennsylvania, speed reduction at hazardous intersections should consider infrastructure improvements. Countermeasures are primarily intended for consideration on the through approaches at stop-controlled intersections; however, they may also be considered for high-speed approaches at signalized intersections.

A number of countermeasures have performed well under limited usage, but results are not conclusive. Examples are:

- Lane narrowing using rumble strips parallel to the edge lines
- Lane narrowing using raised pavement markers on approaches where noise issues or bicycle safety concerns associated with rumble strips cannot be addressed
- Dynamic warning signs on the through approach warning drivers traveling at speeds above a set threshold to slow down
- Peripheral transverse pavement markings

-
- High-friction surface applied to the approaches and through the intersection

A systemic deployment of “yield to pedestrians” channelizing devices reduced pedestrian-involved crashes almost 12% in the past five years.

Iowa

A recent CTRE study looked at a handful of sites in small rural communities, each town using different calming techniques. The purpose of the study was to evaluate traffic-calming treatments on the major roads through small Iowa communities, using either single-measure low-cost treatments or gateway treatments. Five rural Iowa communities implemented and evaluated different low-cost traffic treatments:

- On-pavement speed signs
- Lane narrowing using shoulder widening
- Converging chevrons
- Transverse pavement markings (optical speed bars)
- Speed feedback signs
- Color pavement speed markings
- Island treatment from tubular markers
- Speed tables

Before the treatments were implemented, it was noted that drivers passing through the community often entered at high speeds and maintained those speeds as they traveled through the community. After implementation, it was determined that the speed feedback signs, tubular island, and speed tables were the most effective treatments.

Conclusions

Lessons learned were the need to consider the appropriate design vehicle (e.g., farm equipment) and the targeted population (e.g., perhaps older individuals) and address snow and ice issues. Future maintenance issues also need to be considered, especially for small communities with limited resources. Residents and officials of small communities may need to be educated about traffic calming. Stop signs are not traffic-calming devices.⁴⁴

Results for both Michigan’s and Iowa’s efforts were mixed. Community acceptance of the proposed treatment was paramount for long-term acceptance. Speeds were temporarily reduced for some treatments; however, they eventually rebounded to precalming levels. After the DOT study’s conclusion, the affected communities in each state requested the removal of at least one installation.

⁴⁴ Traffic Calming on Main Roads Through Rural Communities, <http://www.fhwa.dot.gov/publications/research/safety/08067/>

Removal of Fixed Objects and Roadside Hazards

Pennsylvania

PennDOT is employing a systemic removal of frequently hit trees and relocating roadside utility poles. This has reduced these crashes 9% over the past five years.

All of the utility pole high crash locations in Pennsylvania are on only 4% of the state highway system. This high concentration of these types of crashes in a small amount of roadway length implies that a plan to reduce the utility pole crashes at these locations can have a major impact statewide on the initiative to reduce the frequency and severity of these crashes.

Districts are provided with an annual list of ranked utility pole crash clusters (i.e., three or more hit utility pole crashes within a half-mile roadway segment). From this cluster list, the districts formulate an improvement plan to reduce the number of hit utility pole crashes cost effectively. Safety improvements are implemented using the pole-crash cluster decision tree shown in Figure 3.7.

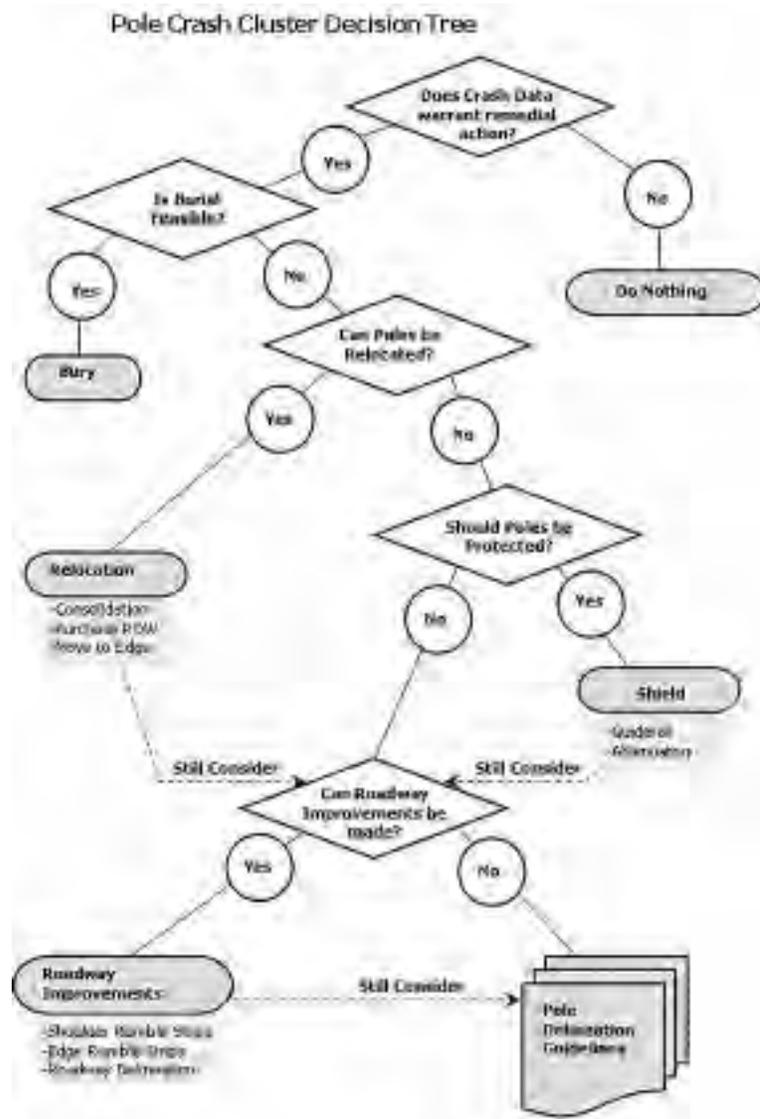


Figure 3.7 PennDOT utility pole decision tree

The safety improvements shown in the utility pole-crash cluster decision tree are as follows:

- Burial of utility lines
- Relocation of utility poles (preferably to edge of clear zone)
- Consolidation of poles to one side of the roadway
- Road improvements (including SRS or ELRS)
- Protection (impact attenuators or crash cushions; however, this improvement is rarely made)
- Pole delineation (last option)⁴⁵

Washington State

Washington State found that 85% of its lane-departure collisions hit an object (i.e., a guardrail embankment; a ditch, pole, or tree; or a concrete barrier); the remaining 15% overturned.

WSDOT uses systemic improvements, including updating guardrail, installing CMB, rumble strips, and an inventory of roadside features. In 2007, WSDOT was the first agency to adopt the 31-inch-high guardrail as standard for new installations. Based on the MGS system, it meets current FHWA Manual for Assessing Safety Hardware (MASH)⁴⁶ crash-testing criteria. The agency found that there was no increase in cost per lineal foot compared to the old guardrail design. WSDOT has installed over 500 miles of this guardrail.

Missouri

MoDOT's first priority is to keep vehicles in their lanes and on the roadway. However, while these efforts are critical to roadway safety, drivers will continue to make mistakes. MoDOT believes that it is vital to improve the roadsides where possible. This may mean removing a tree or possibly relocating a utility pole. It may also mean installing guardrail in certain situations. Documentation proves that when a vehicle leaves the roadway in Missouri, it will most often strike a tree.

⁴⁵ AASHTO Strategic Highway Safety Plan, NCHRP Project 17-18 (3), Utility Poles: Appendix 3: Pennsylvania's Program to Reduce Utility Pole Crashes; 2004; http://safety.transportation.org/htmlguides/site_map/default.htm

⁴⁶ FHWA Manual for Assessing Safety Hardware, http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/ctrmeasures/mash/

Data Management and Analysis

Having appropriate and available crash data was another critical issue faced by the agencies visited as part of this scan tour. Agencies that are adept at processing crash data are better able to allocate scarce resources. These agencies had experienced a variety of problems with data:

- Who “owns” the data
- Crash report accuracy
- The ability to electronically input the data (especially geographical coordinates)
- The timeliness and ease of querying
- The ability to generate reports and maps in various formats

Michigan

Michigan LTAP, in cooperation with MDOT, enhanced the RoadSoft Safety Module to assist local agencies in identifying a location of concern, obtaining detailed safety analysis, and integrating crash data into reports and collision diagrams. The RoadSoft software is an asset management tool that includes a traffic safety analysis module for cities and counties.

RoadSoft provides local road agencies with the tools and services that will improve the safety of their roads while helping MDOT achieve statewide safety goals. All public agencies in Michigan receive RoadSoft at no charge. Parts of the software’s safety module include:

- Detailed safety analysis – Analyze intersections, segments, and curves; generate graphs to provide visual representations of trends; identify roads eligible for federal safety funding; and more
- Integrated crash data – Compare crash data to roadway layers (e.g., signs and signals); overlay aerial photos and navigate through all levels of detail, including a public copy of the actual crash report
- Standard crash reports provide several levels of detail; advanced filtering features allow unlimited reporting capabilities and collision diagrams⁴⁷

⁴⁷ “Powerful traffic safety analysis for cities and counties,” RoadSoft Roundup, Vol. 8, No. 2, February 2008, <http://www.roadsoft.org/system/files/RoundUpV8N2.pdf>

“RoadSoft not only empowers local road agencies to examine their own crash data, it also provides us a common set of tools so we can more easily partner with them.”

~Michigan DOT

MDOT’s Local Safety Initiative assists local agencies with traffic engineering services, advising them on road safety issues and providing funding assistance.

Pennsylvania

PennDOT provided “crash data law enforcement liaisons” to police agencies to improve the timeliness and accuracy of crash reports. The results were dramatic, with crash data being available to end users in just 20 days, reduced from 230 days in 2004. PennDOT’s goals for data management are to improve the timeliness and quality of both crash data and local road data. The state is striving to have 100% electronic submissions by 2012.

Pennsylvania has been using its Crash Data Analysis Retrieval Tool⁴⁸ (CDART) and has data back to 1997. CDART is a database querying system that allows fast retrieval of crash data using any one of 60 filtering parameters. This Web-based GIS application provides PennDOT highway safety engineers, traffic engineers, maintenance personnel, and project designers the capability of analyzing crash data collected through the state crash reports and allows the users to create, store, and query data, and to display the results in several formats, including maps, spreadsheets, and reports. Safety engineers established a series of attributes used to query 200,000 crash records annually. About 350 users from PennDOT and state police and planning organizations are able to access CDART.

Georgia

In 2005, GDOT took over ownership of the state’s crash data from multiple generators statewide in an effort to unify various problems in data quality and timeliness. In an effort to provide further efficiencies, GDOT has been improving data collection and in 2010 contracted with Open Portal Solutions⁴⁹ to utilize the resources of electronic reporting.

Georgia Electronic Accident Reporting System⁵⁰ (GEARS), developed and maintained by Open Portal Solutions, provides free software, training, and ongoing technical support to local law enforcement agencies. GEARS allows authorized users to electronically capture and submit crash data directly to GDOT after running internal validation tests to ensure the data’s quality. GEARS reduces the time and resources involved in submitting reports and allows local agencies free access to the GDOT system to extract data and generate reports tailored to their specific needs. As of

⁴⁸ Crash Data Analysis Retrieval Tool (Version 1.13; Participant’s Workbook), <ftp://ftp.dot.state.pa.us/transfer/CDART/CDART%20Manual%20v13%2007062010.pdf>

⁴⁹ Open Portal Solutions, <http://openportalsolutions.com/>

⁵⁰ Georgia Electronic Accident Reporting System, <https://gearsportal.com/Pages/Public/Home.aspx>

2010, about 34% of all crashes were reported electronically.⁵¹

Minnesota

MnDOT uses two approaches to analyze routes and/or systems to determine which segments to treat. The first is black spot analysis for locations with a known quantity of crashes (e.g., severity ranking and critical crash rates). The agency looked at site-specific locations, comparing the number of crashes to the network average, checking to see if the locations are significantly overrepresented (with a focus on severe crashes).

The second approach is a systemic risk assessment in which MnDOT assesses various factors known to contribute to fatal and severe-injury crashes. The agency looked at volumes, road-departure crash density, access density, curve density, edge risk (shoulder and clear zones), and passing zone frequency.

Wright County, Minnesota

Wright County reports that the Minnesota Crash Analysis Mapping Tool⁵² is very helpful. The tool enables users to analyze crash data based on a number of attributes, including county, city, and number of crashes. This graphical application provides transportation professionals with a powerful tool for grouping and analyzing crash data. The application produces a map with plotted crash locations and a series of charts and automated crash reports based on selected crash data. The software uses data filters to reduce the number of selected incidents, allowing users to customize crash data searches to their requirements.

Colorado

CDOT reports that it has excellent data that provides the means to determine appropriate countermeasure treatments. However, it also reports that the data is not all encompassing, as there are limitations of the resources required to collect and manage the information. It is able to collect and report on all crash types, severities, and road and weather conditions.

Risk is determined by a cost-benefit analysis, but Colorado believes that the commonly used measurement of crash data, crash rates, is misleading. According to CDOT, another method to measure safety is needed. According to the agency, that method is its SPF.

“In order to manage safety effectively, we need to be able to measure it.”

~Colorado DOT

By plotting crashes per mile per year for roadway classifications, CDOT generates a scatter plot of crashes, which allows it to develop a concept it calls LOSS, which is based on the concept of SPF. LOSS describes the degree of safety, or lack thereof, on a roadway segment and allows a risk

⁵¹ Letter from Commissioner Vance C. Smith Jr. to law enforcement agencies, Georgia DOT, July 23, 2010

⁵² Minnesota Crash Analysis Mapping Tool, http://www.dot.state.mn.us/stateaid/sa_crashmapping.html

assessment to be made on the necessity, and nature of, safety improvements on all projects.

Colorado furthers SPF by incorporating pattern recognition and diagnostic algorithms, which compare 84 patterns with the normal values for a roadway segment under consideration to determine the roadway segment's LOSS. Specific countermeasures can then be directed to solving the problem.

CDOT implemented this effective methodology on all projects in 2002. Since that time, the million vehicle miles traveled mileage has stayed consistent, but the number of fatal crashes has dropped 40% from 677 in 2002 to 409 in 2010.

Mendocino County, California

On a smaller scale, Mendocino County's crash data is processed manually, but is reviewed in a timely manner so that any urgent corrective action can be taken. Crash information is logged by date, time, and milepost, and is more useful if it is entered in a spreadsheet format. It has found that an accurate milepost system, GIS-compatible database, and even an electronic sign inventory database are desirable support systems that should be in place.

Washington State

Washington's Roadside Features Inventory Program⁵³ (RFIP) is a corporate program for collecting, storing, and reporting roadside features (e.g., guardrails, culverts, signs, objects in clear zones, and other features) from all WSDOT regions. This information is used for asset management, project and system design, and overall system analysis.

Previously, many individual business areas within WSDOT have collected similar information (e.g., utility poles, signs, guardrail, tree groupings, and slope information) independently of one another. This caused duplicate efforts and expense, resulting in the data not being consistently stored in a corporate standard format that would allow it to be shared and maintained.

Because of the advancements in technology, GIS applications, and the creation of the RFIP, WSDOT has combined this information, thus creating a single source for data retrieval. Project benefits include more consistent and accurate data, reliable data collection, and agency savings in both time and money, because its ability to analyze and maintain the data has increased exponentially.

WSDOT devoted 15 years to entering all of its highway data into electronic format and now uses it to convince the state legislature that WSDOT is doing the right projects in a cost-effective manner.

“The message resounded loud and clear: it is the data that drives the plan.”

~Washington State DOT

⁵³ Washington State DOT Roadside Features Inventory Program, <http://www.wsdot.wa.gov/mapsdata/roadway/RFIP/default.htm>

Missouri

MoDOT uses data to evaluate crash types. Since the late 1990s, MoDOT has relied on Transportation Management System (TMS) data to drive decisions. The TMS data is used daily to evaluate crash types and was used in the development of MoDOT's SHSPs. Many of the agency's performance measures require data from TMS.

Performance Measures

The scan team found that meaningful and relevant performance measures seem to be another factor necessary for attaining continuous safety improvements. Agencies that deliver timely and complete safety data and use periodic and formal reviews are the ones that find and eliminate deficiencies.

Pennsylvania

PennDOT’s safety program consists of a low-cost safety improvement program to drive safety project selection. Pennsylvania uses a “plan, do, check, act” model in developing, implementing, and tracking progress and re-evaluating its SHSP. The agency developed specific task-measurement dials that make it easy to give quarterly reports to its leadership on the agency’s progress toward meeting its goals (see Figure 5.1). The partners and stakeholders meet annually to review strategies and evaluate the progress made towards the plan’s goals.

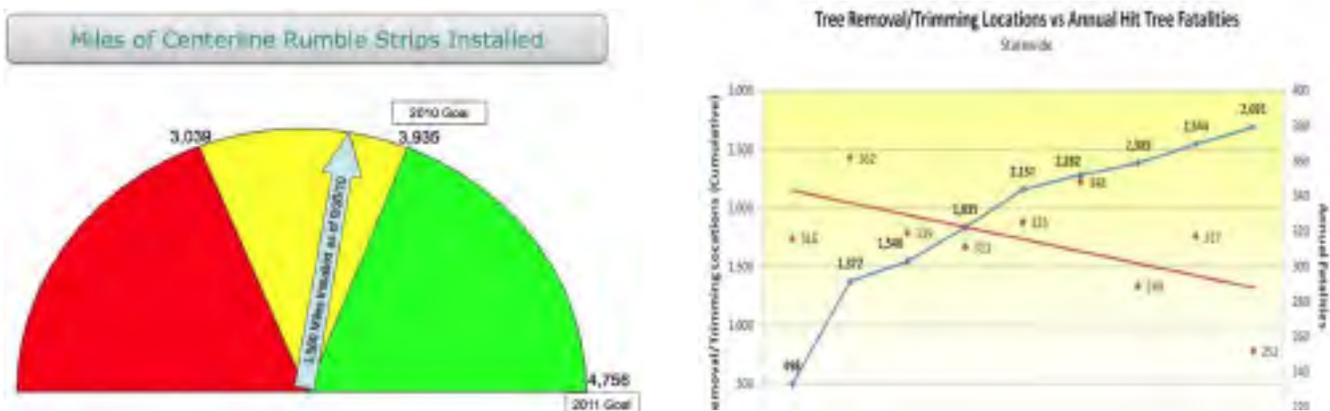


Figure 5.1 Examples of PennDOT’s tracking dials and trend charts

Local safety summits held in each of the 11 PennDOT engineering districts help the agency achieve shared ownership. The summits’ results are district safety plans that directly support the SHSP and involve the local partner and stakeholder organizations.

Each PennDOT district executive has performance measures related to safety, and these measures are included in the:

- State highway safety summary report
- District highway safety summary reports
- SHSP tracking dials

The agency’s use of measurable and accountable performance measures instills a statewide culture of safety.

Minnesota

MnDOT has a performance measure for safety through its “Towards Zero Death” program partnership, whose goal is zero fatalities and serious injuries. The agency has developed interim goals to track progress. Each office recommends a set of measures based on best practices, research, and available data. These measures are incorporated into the department’s performance measures.

Mendocino County, California

Mendocino County submits an annual report to its county commissioners as a way to formalize recommendations as a basis for work orders and to secure funding. Reviewing these annual reports helps identify persistent collision locations, and these then become candidates for the services of the state’s road safety audit team.

Washington State

Performance measurement at WSDOT is agency wide, and performance reporting is a high priority. Data tracking, measurement, and reporting methods are continuously refined.

“An often-used motto at WSDOT is, ‘What gets measured, gets managed.’”
~Washington State DOT

In Washington, *The Gray Notebook*⁵⁴ (originally titled *Measures, Markers, and Mileposts*) is a foundation for assessing and reporting agency performance. *The Gray Notebook* provides quarterly, in-depth reports on agency and transportation system performance to keep WSDOT accountable to the governor, legislators, transportation organizations, and the public.⁵⁵

The analysis of performance measures adheres to WSDOT’s “no surprises” philosophy for the agency’s heads-up style of early and timely reporting of performance. Performance is assessed whether it is good or bad, no exceptions.

The largest impact of measuring and reporting performance results has been the increased confidence of the Governor, Legislature and the public in the projects and programs managed by WSDOT.

Missouri

MoDOT’s Tracker⁵⁶ identifies numerous performance measures, many involving safety. Division- and district-level Tracker performance measures feed into the state-level Tracker and may involve

⁵⁴ Washington State DOT’s *The Gray Notebook*, <http://www.wsdot.wa.gov/NR/rdonlyres/BFB0C36A-DC7E-4BF5-B283-9864C36A7B9C/0/GrayNotebookJun11.pdf>

⁵⁵ Performance Measurement at WSDOT – Overview and Lessons Learned, *Measures; Markers and Mileposts*; May 2007, <http://www.wsdot.wa.gov/NR/rdonlyres/0ECE7DB2-D955-4E0A-954B-1F55C220D5F8/0/GrayNotebookJun07.pdf>

⁵⁶ MoDOT Tracker, http://www.modot.org/about/general_info/Tracker.htm

more specific initiatives. For instance, one Tracker may compare lane-departure safety initiatives (e.g., miles of rumble stripes) and lane-departure fatalities.

Funding Sources and Issues

Funding of lane departure strategies and countermeasures was an issue everywhere the scan team visited and throughout the country. However, successful agencies do manage to find money for safety projects. Sources include Safe, Accountable, Flexible, Efficient Transportation Act: A Legacy for Users (SAFETEA-LU)⁵⁷, state set-asides, and Section 154 or 164 funding.

SAFETEA-LU authorized the federal surface transportation programs for highways, highway safety, and transit for the federal fiscal years 2006 to 2009. SAFETEA-LU expired September 30, 2009, but is continuing under extensions. Congress has extended SAFETEA-LU through the end of fiscal year 2011, freezing funding at 2010 levels for transit and other programs through September 30.

Some of the funding provisions of SAFETEA-LU are found in these sections:

- Section 402, State and Community Highway Safety Grants
- Section 405, Occupant Protection Incentive Grants
- Section 406, Safety Belt Performance Grants
- Section 408, State Traffic Safety Information System Improvement Grants
- Section 410, Alcohol-Impaired Driving Countermeasure Incentive Grants

States were required to enact an open container law. If they had not done so, a small percentage of National Highway System, Surface Transportation Program, and Interstate Maintenance funds were transferred to the state's Section 402 program. The transferred funds had to be used for impaired-driving programs. All or a portion of that amount can be transferred into the state's hazard elimination program.

The repeat offender transfer provisions were also authorized under the Transportation Equity Act for the 21st Century⁵⁸ (TEA-21). As with the Section 154 program, federal responsibility for the transfer provisions rests with the National Highway Traffic Safety Administration and FHWA. Section 164 requirements are that states must enact a "repeat intoxicated driver law" or face consequences that are similar to those for the open container transfer provisions. The law must apply to anyone convicted of a second or subsequent DWI or DUI offense in any five-year period.

⁵⁷ Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users, <http://www.fhwa.dot.gov/safetealu/>

⁵⁸ Transportation Equity Act for the 21st Century, <http://www.fhwa.dot.gov/tea21/>

Pennsylvania

Each year, PennDOT invests approximately \$10 million in state funding to implement low-cost safety improvements throughout the state. It receives between \$35 and \$40 million in federal funding annually for its HSIP. As with the other states, this funding is distributed to PennDOT's planning regions based on the number of lane miles, vehicle miles traveled, fatalities, and crashes. Pennsylvania recently received more than \$28 million toward its highway safety program through a federal grant awarded for recording high seatbelt usage rates in consecutive years.

PennDOT is implementing a policy for limiting the use of HSIP funds to high crash locations and proven, systemic, low-cost safety improvements to drive down fatalities. The agency's Rural Road Safety program is funded by HRRR (\$2 to \$3 million each year) and the LCSIP programs. Additional funding is available from HSIP (Section 148), LCSIP (Section 715), and Section 406 funds.

South Carolina

SCDOT receives safety funding from the state government, in addition to federal HSIP funding. Funding for FY2010 was \$16 million, which was to be used on the agency's rural road safety program.

Georgia

The GDOT local agency off-system program has \$7 million available for off-system safety improvements, with no matching funds needed by the local agencies. GDOT provides road safety audits and other assistance to counties so that they are able to apply for safety funds.

Minnesota

The Minnesota Transportation commissioner's staff directed that safety-funding goals be established for each area transportation partnership (equivalent to district or regions in other state DOT organizations) and that this money be shared with local agencies based on the data.

Two primary sources of funding at MnDOT are HSIP (\$20 million) and Section 164 sanction funding (\$5 million). Section 164 funds are sometimes used to supplement HSIP funds, depending on the success of the current solicitation process. Section 164 funds are also used to fund standalone safety initiatives, such as:

- CMB
- County road safety plans
- High enforcement of aggressive traffic (HEAT)
- Enhanced pavement marking study

Wright County, Minnesota

Local entities have far fewer resources to work with when compared to state or federal agencies. In Wright County, limited funds dictate many of the safety solutions available to local transportation

agencies. Most funding for the county’s activities is from HSIP, but these additional sources are also available:

- Rural road safety account
- Minnesota’s highway safety program
- High-Risk Rural Roads program⁵⁹
- A local levy
- State aid construction funds

Funding is clearly one of the major challenges to developing and implementing rural safety programs and plans. The county’s recently completed CRSP identified over \$3 million in suggested safety projects, a figure that far exceeds the available amount of funding.

Iowa

Dedicated federal and state safety funding sources for Iowa are HSIP, state safety funds (TSF/TSIP), and state “management systems.” Iowa shares alternative sources of funding like the federal traffic records funds from the National Highway Traffic Safety Administration. The DOT also funds the multidisciplinary Iowa Traffic Safety Alliance. Those funds are used to help support the local and multidisciplinary aspects of the state’s CHSP.

Missouri

MoDOT uses the Section 154 Open Container Transfer Provision to transfer funding for safety improvements. Missouri also qualifies for the Section 164 Repeat Offender Transfer Provision.

Colorado

Funding programs utilized within Colorado are federal hazard elimination, Congestion Mitigation and Air Quality Improvement program⁶⁰, transportation commission, grants, and others.

Alternative sources of funding are Transportation Commission funds, tolling, and public/private partnerships.

Colorado’s access to state funds from licensing fees enables it to fund safety projects. In 2009, the General Assembly passed FASTER, which changed the way that transportation funding works in Colorado. The FASTER bill established or modified a number of new operating, funding, and oversight mechanisms and programs for a variety of transportation categories, including the Road Safety Fund.

⁵⁹ This program is a component of the HSIP and is set aside after HSIP funds have been apportioned to the states. It provides \$90 million of HSIP apportionment per year.

⁶⁰ CMAQ originated with the Clean Air Act of 1990.

FASTER took effect on July 1, 2009. Funding primarily comprises car rental fees and weight-based vehicle registration fees. It is projected to generate approximately \$265 million annually for transportation improvements. Monies collected under the FASTER Safety Fund are to be used for construction, reconstruction, or maintenance projects that the Transportation Commission, a county, or municipality determine are needed to enhance the safety of a state highway, county road, or city street.⁶¹

Washington State

WSDOT, much like other state transportation agencies, has set-asides for high-risk rural roadways. The estimated HSIP funding for Washington State is \$98.3 million, which is shared with local agencies. To complement the HSIP funds WSDOT receives, the Washington Traffic Safety Commission and the Washington State Patrol qualify for federal highway safety grants that, together, total about \$12 million per year. In addition, the state has funded many safety projects with funds from the state gas tax. These federal funds are typically invested in programs to change behavior, primarily through education, enforcement, providing equipment, and implementing new technologies.

⁶¹ “FASTER – A Dedicated Funding Source,” CDOT Annual Report FY 2009–2010, p 23, http://www.coloradodot.info/library/AnnualReports/AnnualReport_2010_downloadable.pdf/view

Partnerships in Education and Enforcement

A basic principle of highway safety is that the overall safety of a roadway system must take into consideration other aspects of the driving experience. The vehicle, the roadway, and the driver contribute to approximately 10%, 33%, and 93% of crashes, respectively. As a result, it is imperative that the approach to safety solutions be multidisciplinary. Arguably, the most common application of this multidisciplinary approach exists in the form of the 4 E's of highway safety:

- **Engineering** to deploy safety countermeasures (improvements)
- **Education** on roadway safety
- **Enforcement** of safety laws and regulations
- Effective **EMS**

This scan team primarily looked at engineering solutions; however, the team found that agencies with successful traffic safety programs are more likely to team up with other interested parties to create synergistic program efficiencies.

Michigan

Partnerships are beneficial when introducing a new product. For example, MDOT uses targeted outreach to educate the public, first responders, and its own workforce on the nature of cable barrier. In its “Median Man” campaign, a fictitious superhero is described as educating Michigan motorists about the life-saving benefits of hundreds of miles of new cable guardrail being installed on Michigan highways (see Figure 7.1). The character is featured on the MDOT Web site, in radio spots aired throughout the state, in a YouTube video, and in printed brochures.



Figure 7.1 MDOT educational campaign

Many emergency responders and maintenance personnel harbor concerns about the safety of working around the high-tension cable system. MDOT developed another aspect of this public outreach by offering a first responder flyer and video, educational tools on the correct procedure for approaching a crash site involving cable.

MDOT reached out to the public, to emergency responders, and to maintenance staff in order to educate them about CMB. They developed the “Median Man” campaign with public service announcements, informational flyers, and project-specific training. Slide presentations and dedicated Web pages are all used to dispense information to various stakeholders about cable (and rumble strips, as well). Various media titles include:

- “Median Man”
- “Cable Guardrail in Michigan”
- “Please Don’t Cut the Cables”
- “Sound of Saving Lives”
- “Rumble Strips & Rumble Stripes”
- “Understanding Non-Freeway Rumble Strip”

Pennsylvania

Educational outreach includes Pennsylvania’s “Drive Safe PA” program and a multi-partner Web site that acts as a warehouse of traffic safety information on a wide variety of lane-departure subjects. The program is a cost-effective, data-driven approach to driver education involving over 300 enforcement agencies, covering such topics as aggressive and impaired driving.

Determined bicycling groups have approached many transportation agencies with concerns about the use of SRS and ELRS. In PennDOT’s case, the state reached out to the cycling community to gather wider support. This outreach seems to be beneficial to both the cycling community and to the transportation agency. Both groups learn each other’s positions and concerns and are then able to work together to solve issues.

South Carolina

SCDOT staff spoke of the challenge of developing trust and a working relationship with bicycling groups. The agency has received complaints from the public regarding the noise generated from rumble strips and has worked to resolve those issues. SCDOT joined efforts with Department of Public Safety for both enforcement and education to use radio, television ads, and press releases to educate the public about lane-departure issues.

A key component of the awareness campaign is a television public service announcement focusing on prevention of ROR crashes. Through the assistance of the SC Broadcasters’ Association, this PSA has appeared across the state. In addition, a DVD was created to educate drivers on how to prevent ROR crashes and how to recover safely if they do. Drivers’ education teachers, law

enforcement personnel, and EMS personnel use the DVD.

Through a grant from the Roadway Safety Foundation, SCDOT launched a statewide campaign to educate the public about the safety benefits of rumble strips. The campaign included a television PSA, a radio PSA, and a brochure:

- The “Recognize-React-Recover” education program (see Figure 7.2) includes a DVD and associated materials for educating drivers about inattentive driving and the issues related to ROR crashes.
- The “Over the Edge and Back” brochure describes how SRS can save lives.
- The “Be Tire Smart! Play your PART” brochure, where PART is an acronym for pressure,



Figure 7.2 SCDOT educational campaign

alignment, rotation and tread, encourages motorists to adopt good tire maintenance practices.

SCDOT also partnered with the South Carolina Highway Patrol for the enforcement of speeding and DUI laws.

Iowa

Iowa DOT directs most of its strategic education to its district staff and county engineers, not necessarily to the public. It sees the need to educate upper management and works with various offices (e.g., design, materials, construction, districts, and maintenance) to develop sound policies about the new countermeasure standards. In particular, one challenge was to overcome the departmental concern that milled rumble strips and safety edge would decrease pavement life.

Enforcement measures are integral to all of Iowa DOT's countermeasures because shared data findings with law enforcement help support the agency's efforts. Iowa DOT provides crash data and crash maps to the Governor's Traffic Safety Bureau to help it direct enforcement toward corridors with high concentrations of crashes related to speeding, alcohol, and low-seatbelt use.

Colorado

CDOT safety attempts to leverage the 4 E's of highway safety in its program development and implementation. The education component is especially important to CDOT's behavioral safety programs.

The agency's public relations department is very active in promoting traffic safety programs. Campaigns include, but are not limited to, speed enforcement, impaired driving enforcement ("The Heat Is On!"), and distracted driving. The agency's public relations department conducts an annual phone survey that solicits public feedback regarding traffic safety awareness.

Enforcement measures have been shown to be the single most effective activity in behavioral traffic safety programs. In the areas of occupant protection, speed enforcement, and impaired driving, CDOT's public relations department initiates focused campaigns in geographical areas selected based on crash data analysis followed by enforcement conducted by the Colorado State Patrol, sheriff departments, and police departments. According to the traffic safety research, high-visibility enforcement programs typically have a ratchet effect: the desired behavior normally increases during and immediately after the program and then decreases somewhat, but remains at a level higher than the preprogram level.

Some state agencies are actively using social networking (i.e., Facebook, Twitter, and YouTube) to get the word out. CDOT took education to a new level when it funded a smart phone application that lets users calculate their blood-alcohol level. CDOT's "R-U-Buzzed? BAC Calculator" is a free smart phone app that allows users to calculate their estimated blood alcohol concentration. While the calculator is only a guide, the app suggests that having a sober driver is the only safe option, and it will even provide the phone number of a local cab company.

Washington State

WSDOT found that engineering alone is not the answer, and that infrastructure improvements are not a solution for most crashes. It has determined that the other E's of highway safety are more effective in some cases.

Local transportation agencies are also realizing the cost-effective synergies of partnering. However, the political reality is that local government executives make some decisions and may not be in the best interest of highway safety.

Missouri

MoDOT is very involved in working with partners to achieve success. To reduce fatalities on its roadways, the agency has partnered with the state's enforcement and education communities and with EMS. Much of this discussion is documented in Missouri's SHSP (Missouri's Blueprint to ARRIVE ALIVE⁶²).

⁶² Missouri's Blueprint to ARRIVE ALIVE, <http://www.savemolives.com/>

Institutionalized Culture of Safety

During the state visits, the scan team noticed that the organizational culture of the transportation agency had a direct and positive correlation with the success of various countermeasures for mitigating the effects of lane departures. The first of these correlations was the presence of an advocate within the agency who made it a personal mission to improve safety. Usually the advocate was directly involved in safety programs and in a position to be able to affect changes in the status quo of an agency. Even local agencies can have a culture of safety, and even if there is only one advocate, such as the scan team found in both Wright and Mendocino Counties.

A second correlation found in successful agencies was an attempt to institutionalize safety by taking successful strategies and codifying them into departmental policies (e.g., directives, standard operating procedures, standard plans, and design manuals). Not only does formalizing countermeasures results in wider acceptance, it also has an added benefit of providing future continuity of the safety program within a department if the advocate retires or otherwise leaves the position.

Finally, top performing transportation agencies strive to encompass safety in every aspect of the department. From planning, design, funding, construction, and beyond, these departments envelop safety from the top-management staff down to hourly workers. The amount of resources that these agencies devote to safety was enormous. These organizations take highway safety from a lower level program and advance it into a system-wide culture.

Pennsylvania

PennDOT's Multi Agency Safety Team (MAST) is made up of various stakeholders with a common interest in highway safety (see Figure 8.1). MAST includes leadership from various state agencies and functions as a lead for traffic safety within Pennsylvania. Its functions are:



Figure 8.1 PennDOT's multiagency approach fosters a culture of safety

- Approve and oversee implementation of the CSHIP

- Prepare a quarterly summary of achievements and successes for the governor's office
- Enforce accountability by reviewing actions/reports from task groups
- Evaluate plan and its performance

Minnesota

MnDOT established its Toward Zero Deaths⁶³ (TZD) program to create a culture in which traffic fatalities and serious injuries are no longer acceptable through the integrated application of education, engineering, enforcement, and emergency medical and trauma services. These efforts are driven by data, best practices, and research. TZD is an interagency partnership that includes representatives from the state's Departments of Transportation, Public Safety, and Health; Minnesota State Patrol; FHWA; and the Center for Transportation Studies at the University of Minnesota. The partnership's vision is to reduce fatalities and serious injuries on Minnesota's roads to zero, with short-term goals to include fewer than 350 traffic-related fatalities, and fewer than 850 serious injuries by 2014.⁶⁴

A key aspect of a culture of safety within an organization is whether the safety program has lasting durability, especially if a proponent or advocate leaves the agency or moves to a different position. To its credit, TZD has remained in place since 2003 under the leadership of three different commissioners and two different state traffic engineers.

Washington State

WSDOT formally adopted its Target Zero⁶⁵ vision in 2000, becoming the first state to adopt such a goal. The goal is to eliminate all traffic deaths and serious injuries on Washington roads by the year 2030. The transportation agency's HSIG is a major component of any success the vision has achieved.

Key elements of this vision have many partners, viable databases, and realistic state goals and priorities and use a mix of proven countermeasure strategies. This method reflects the belief that implementation of this plan will reduce deaths, while also acknowledging that there are factors outside of the control of the Target Zero partners. Trends in the driving population (e.g., the number of people on the road and therefore exposed to the risk of traffic collisions) can affect the number of traffic fatalities. Meanwhile, technological improvements and medical advances can reduce the risk of fatalities. All of these factors and more (see Figure 8.2) will influence WSDOT's ability to reach zero fatalities and zero serious injuries by 2030.

⁶³ Toward Zero Deaths, <http://www.minnesotatzd.org/index.html>

⁶⁴ Toward Zero Deaths Strategic Direction, 2010, <http://www.minnesotatzd.org/about/documents/strategicdirection.pdf>

⁶⁵ Target Zero, <http://www.wsdot.wa.gov/planning/SHSP.htm>

■ Independent commission structure with broad representation from state and local agencies
■ Strong partnerships among the state agencies and the governor
■ Data-driven, research-based planning and programming
■ Strong network of local community-based programs and resources that are assisted by the
■ Strong network of local community-based programs and resources that are assisted by the state agencies
■ Intensive legislative involvement
■ Champions in the legislature who deliver key safety initiatives
■ Strength of the House and Senate transportation committees in managing all transportation funding and support of public policy issues
■ A formal system of performance accountability to the governor, public, and legislature
■ An aggressive Target Zero goal prior to and now within the current SHSP

Figure 8.2 *Washington State DOT's critical success factors for a Target Zero vision*

Missouri

Missouri has implemented two SHSPs to date, with the current one called “Missouri’s Blueprint to Arrive Alive.” The Blueprint has identified numerous focus areas and strategies that cover the 4 E’s of highway safety. The Blueprint is an identified fatality-reduction goal for a specific year. The DOT considers the Blueprint to be very important to the agency’s success to date.

The Blueprint is successful due to many factors, including the 10 regional coalitions that are all working to educate, enforce, engineer, and improve response. Subcommittees focus on specific issues/agendas (e.g., older driver, motorcycles, and young drivers). These efforts, along with the system-wide safety initiatives, are allowing the numbers to decrease. Since 2005, Missouri has seen fatalities decline for five straight years, from 1,257 in 2005 to 821 in 2010. MoDOT hopes that this trend will continue.

The agency believes in the system-wide safety initiatives; they use data and “tier” the locations for improvements (e.g., median guard cable, rumble stripes, and top horizontal curves. Efforts are evaluated through documented performance measures, and MoDOT makes evidence-based decisions. The Blueprint drives the agency’s efforts.

Summary of Findings

In this report, the scan team has detailed many of the cases where transportation agencies targeted and successfully addressed safety problems utilizing low-cost efforts at spot locations or throughout their jurisdictions. The team also found that while the solution for one problem may be well known within one transportation agency, the implementation of a solution might not be well known in other agencies. Thus, it is the team's hope that the publication of this report will facilitate the transfer of successful knowledge and practices to transportation agencies throughout the country.

The team saw a strong correlation between the culture of safety within a transportation agency and positive results in reducing the number of lane-departure crashes. While having an institutionalized safety culture should be a goal of every agency, an agency with even one strong advocate in highway safety can achieve positive results in reducing lane-departure crashes.

The team desires to actively support the efforts of agencies that are leaders in the various mitigation factors mentioned in this report. To that end, the team identified several national transportation associations that may have an interest in the findings of the scan tour. Meetings are planned for the Transportation Research Board (TRB), the American Association of State Highway and Transportation Officials (AASHTO), the National Association of County Engineers, and the Institute of Transportation Engineers in 2011, and the team members were tasked to get on their agendas in order to present the scan's findings.

Finally, the scan team found that the agencies the team visited were honored by the recognition of their successes. The professionals of those agencies know that many advances remain to be made in lane-departure avoidance, and all are willing to tell others of their experiences. Therefore, a series of Web seminars is suggested, with the advocating agency presenting its expertise to an Internet classroom.

Amplifying Questions

Administrative

- In what ways does your agency leadership support safety initiatives?
- How do changes in leadership positions at the state level affect ongoing or developing policies or safety programs?
- Is there a traffic safety advocate leading efforts within the agency?

Safety Program

- Does your agency have a Strategic Highway Safety Plan (or similar)?
- What regulations or legislation is applicable to the safety program?
- What safety strategies are important to your agency?
- Were lane departure crashes identified as a critical emphasis area?
- Is your agency satisfactorily progressing with your safety plan (e.g. lane departures, head-on crash mitigation)?

Funding

- How is safety funding provided at your agency?
 - What are the sources of funding?
 - What funding programs are utilized?
 - How is the money divided between competing agencies/programs?
- Is funding centralized or decentralized?
 - How is that accomplished?
- Has the agency identified any unusual or alternative sources of funding?

Strategies

- Do you primarily focus on “high crash” locations (reactive) or do you evaluate system-wide issues (proactive)?
- How much emphasis does your safety planning efforts place on rural areas?
- Which strategies are being implemented first?
 - Why?
 - How?
- How are lane departure strategies being implemented?

Data Management

- What information do you wish that you have, that you currently don't, that would help you to determine what type of treatment to use and where to use it?
 - Better crash data?
 - Better curve data?
 - Better shoulder data?
 - More money?
 - Other?
- What statistics does your state maintain related to road safety?
 - Can these numbers be broken down by urban versus rural areas?
 - Can these numbers be broken down by State vs. Local network?

Data Analysis

- How does lane departure crashes rank related to other crashes on your system?
 - Related to other fatal and serious injury crashes?
- How do you analyze your routes and/or system to determine which segments to treat?
- Describe the methodology used for identification of lane-departure crash locations (site specific vs. system wide).
- How do you treat “high risk” locations?
- How do you determine risk?
- Do you have a rating or ranking mechanism for identifying the highest priority locations to treat?
 - Number of crashes?
 - Crash severity type?
 - ADT?
 - Number of lanes?
 - Divided vs. undivided?

Project Selection Criteria

- Do you do standalone projects?

- Do you treat segments as part of pavement projects?
- What criteria do you use to determine whether you will treat a particular segment of roadway for lane departure crashes?
 - Just crashes?
 - Bike/pedestrian activity?
 - Speed limits?
 - Urban/rural?
 - ADT?
 - Cost?
 - Other?

Countermeasures Used

- What information did you use to help you decide to “try” a particular treatment?
- What are some treatments that you have tried and don’t yet know the outcome (i.e., benefit-cost)?
- What are some treatments that you have tried that you think “don’t work”?
 - Why do you think they failed?
 - Are there modifications that you would make that you think would improve the outcome?
- What countermeasures have been successful? Is the reason known?
- What safety measures are now policies? How is that accomplished within your agency? Please provide standards or policies for these strategies (i.e. drawings, SOP) and any relevant background information (regulations/legislation).

County/Municipal Agency Involvement

- Do local transportation agencies have their own safety plans?
- Are the counties identifying strategies from their own resources, or are they being recommended from the state level?
- What lane departure strategies are being implemented at the local level?

Performance Measures

- Does your agency have a performance measure for safety (e.g., zero deaths, vision zero, etc.)?
- How does your agency identify performance measures?

-
- Does your agency drill down and have measures specifically for lane departure crashes?
 - Beyond reductions in crashes, what other performance measures do you use to determine the effectiveness of these programs?
 - Do county level agencies have performance expectations?

Education and Enforcement

- Does your agency offer educational outreach or invite public involvement in any of these strategies?
- Are Enforcement measures integral to any of the countermeasures?

Results

- What have been the greatest rural program successes in your state?
- Has any emerging strategies been identified?
- Has your agency identified any low cost measures?
- What are some of the obstacles you have encountered when implementing a particular lane departure treatment?
- How have you overcome them?

Challenges

- What do you feel are the most significant challenges to developing and implementing rural safety programs and plans in your state?
- What are the repercussions or issues agencies are being faced with in the implementation of lane departure strategies?
- Are these strategies affecting other roadway variables?
- What areas do you feel need improvement?
 - How could these programs adapt to solve the problems you have identified?

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APPENDIX D: SCAN TEAM BIOGRAPHICAL SKETCHES

Appendix D:

Scan Team Biographical Sketches

MARK NELSON (AASHTO Chair) currently serves as the safety division director for the North Dakota DOT (NDDOT). Nelson's primary duties include management of the traffic safety office, Safe Routes to School, crash reporting, and data analysis sections. He chairs both the Strategic Highway Safety Plan and Fatal Crash Review Team committees for the NDDOT. The safety division administers NDDOT's federal grants programs pertaining to traffic safety and works in cooperation with the agency's engineering division. Nelson served 28 years with the North Dakota Highway Patrol and retired as superintendent in 2009. His background in public safety has been centered around behavioral issues and their relationship to lane-departure crashes. Nelson has a bachelor's degree in criminal justice.

JOHN P. MILLER is the traffic safety engineer in the traffic division for the Missouri Department of Transportation. He manages the Highway Safety Improvement Program, identifies problematic crash types (lane departure), and develops safety program recommendations. He is involved with law enforcement and other safety partners, provides training opportunities, and supports personnel with safety engineering expertise. Miller has been involved in many lane-departure safety issues, including the statewide median guard cable initiative that was launched as part of the agency's system-wide approach to safety. Additional lane-departure safety initiatives involve the milling of thousands of miles of rumble stripes. He received a bachelor of science degree in civil engineering from University of Missouri-Columbia and is a licensed professional engineer in the state of Missouri.

INESSA ZISMAN is the traffic engineer for the Colorado Department of Transportation (CDOT) Region 4 in Greeley. In this position, she manages local agency, safety, and traffic engineering programs for northeastern Colorado. Her primary duties include developing strategies for the implementation of the Colorado Integrated Safety Plan programs and the region's annual \$9 million Traffic Maintenance Level of Service program. She is directly responsible for managing all of Region 4's traffic operations, design and construction of roadway safety improvements, local agency projects, and the utility and access permitting process. She has been with CDOT for 19 years, and in her current position for three years. Previously she held positions in roadway design and construction in various areas of the state. She is a registered professional engineer in the state of Colorado.

CASSANDRA ISACKSON is an assistant state traffic engineer for the Minnesota Department of Transportation (MnDOT). The Office of Traffic, Safety and Technology develops policy, standards, and training for the traffic engineering function in MnDOT and provides technical support to district staff and local road authorities. Isackson's section includes the areas of traffic safety (including Minnesota's Toward Zero Deaths program), signing, pavement markings, work zones, speed limits, tort claims, and traffic standards (including the Manual on Uniform Traffic Control Devices). Minnesota's Strategic Highway Safety Plan identifies lane departure and minimizing consequences of leaving the roadway as a critical emphasis areas. Minnesota state statute gives MnDOT the responsibility for establishing speed limits on all roads, including those owned by local jurisdictions. Isackson's section provides direction to district staff conducting speed studies and is responsible for authorizing speed limits. Prior to her current position, Isackson worked

in a district traffic office developing highway safety projects for construction and worked in the design standards unit of MnDOT. Isackson received her bachelor of science degree in civil engineering from the University of Alabama. She is a registered professional engineer in the state of Minnesota.

DANIEL B. HELMS has served as assistant safety engineer for the Mississippi Department of Transportation (MsDOT) since June 2007. His duties include development of the annual Federal 5% Report, development and analysis of safety projects, testing and development of the Safety Analysis Management System, and working on the development of the Mississippi Strategic Highway Safety Plan, which includes lane-departure crashes as a critical emphasis area. His project management experience includes the Statewide Data Cleansing Project and the development of a local safety training program. He serves as a Technical Advisory Committee member for Mississippi of the Evaluation of Low-Cost Safety Improvement Pooled Fund Study. Helms also spearheaded the MsDOT Traffic Safety's social media presence on Facebook (<http://www.facebook.com/MsDOTSafety> or search "MsDOT Traffic Safety") and Twitter (MsDOTSafety). He has been with the MsDOT since October 2004, previously working as a design team leader in roadway design. Helms received a bachelor's degree in civil engineering from Louisiana State University and a master's of engineering degree, with an emphasis in traffic and transportation and engineering, from Texas A&M University. He is a registered professional engineer in Mississippi and a certified professional traffic operations engineer.

RICHARD B. ALBIN is a safety engineer with the FHWA Resource Center's Safety and Design Team and has been with the FHWA since June 2008. Albin's primary focus is on roadway-departure crashes and roadside design. Prior to joining the FHWA, he worked for 15 years with the Washington State Department of Transportation (WSDOT) and was an assistant state design engineer when he left. In that position, Albin managed the policy and standards section and provided project oversight for one of the WSDOT regions. He currently chairs the TRB Roadside Safety Design Committee and is a member of several NCHRP panels that oversee research on roadside safety issues. He has been a member of AASHTO's Subcommittee on Design and its Technical Committee on Roadside Safety. Prior to joining WSDOT in 1993, Albin worked for six years for the New York State Department of Transportation in a regional office. He graduated from the University of Wyoming with a bachelor's degree in civil engineering. Albin is a licensed professional engineer in Washington State.

DEAN A. FOCKE (Subject Matter Expert) is a retired roadside standards engineer from the Ohio Department of Transportation (ODOT). Focke was a staff engineer in the roadway design policy office at ODOT's central office in Columbus for 18 years. Until he retired in 2009, Focke was involved in the national roadside safety community as a member of AASHTO's Technical Committee on Roadside Safety, AASHTO's Technology Implementation Group on Cable Median Barriers, and the University of Nebraska's Pooled Fund on Roadside Safety. He continues to be active in national and international research as a member of TRB's AFB20 Roadside Safety Design Committee and its subcommittee on international research activities. He chairs NCHRP research panel 22-24, Guidelines for Verification and Validation of Crash Simulations Used in Roadside

APPENDIX D: SCAN TEAM BIOGRAPHICAL INFORMATION

Safety Applications. Additionally, he is a member on NCHRP research panels 22-23 and 22-27. Focke received a bachelor of science degree in civil engineering from Villanova University and an associate of applied science degree in construction management from Columbus State Community College. He is a registered professional engineer in the state of Ohio.

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