APPENDIX A

State DOT Survey Questionnaire

NCHRP PROJECT 20-05: SYNTHESIS TOPIC 48-01 Preventing Roadway Departure Crashes

Dear AASHTO Subcommittee on Safety Management,

Roadway departure crashes are frequently severe and account for the majority of highway fatalities. As reported on Federal Highway Administration's Office of Safety website, in 2014, there were 17,791 fatalities as a result of roadway departure crashes, which was 54 percent of all traffic fatalities in the United States. To address this safety problem, the Transportation Research Board (TRB) is preparing a synthesis on *Practices for Preventing Roadway Departure Crashes.* This is being done for the National Cooperative Highway Research Program (NCHRP), under the sponsorship of the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the FHWA.

The objective of this synthesis is to identify engineering-type countermeasures that are being used by States to prevent roadway departure crashes or reduce the severity of any crashes that occur, and their data-driven advantages and/or disadvantages. The information to be gathered is to include:

- Countermeasures organized by the three risk categories: 1) keeping vehicles on the roadway; 2) minimizing the consequences of leaving the roadway; and 3) reducing head-on and cross-median crashes;
- Relative extent of use, and where or when applied;
- Conventional and innovative countermeasures;
- Implementation hurdles that were overcome (e.g. policy, maintenance, public feedback);
- Programmatic implementation strategies (e.g., hot spots, systematic, systemic); and
- Agency countermeasure evaluations (e.g., before and after safety analysis, Crash Modification Factors (CMF) and/or Safety Performance Functions (SPF), durability studies, life cycle cost analysis).

This questionnaire, along with follow-up interviews and literature review, is being used to gather this information.

This questionnaire is being sent to you as the voting member of the AASHTO Subcommittee on Safety Management for your State department of transportation. If you are not the appropriate person at your organization to complete this questionnaire, please forward it to the correct person. The survey should take no more than 30 minutes to complete.

Background Information for Survey

The questions are grouped into five parts:

I. Respondent Information.
II. Roadway Departure Problem Identification and Implementation Programs—how your state identifies roadway departure problems and programs used to implement countermeasures.
III. Countermeasures Being Used—what countermeasures are being used including their evaluations.
IV. Vehicle-Based Technologies—a look to the not-so-distant future with autonomous vehicles in the traffic stream.
V. Case Examples and Follow-Up.

Questionnaire Tips

- If you are unable to complete the questionnaire, you can return to the questionnaire at any time by reentering through the survey link as long as you access the questionnaire through the same computer. Reentering the survey will return you to the last completed question.
- Survey navigation is conducted by selecting the "prev" (previous) or "next" button at the bottom of each page.

Questionnaire Instructions

1. To view and print the entire questionnaire, click on the following link http://surveygizmolibrary.s3.amazonaws.com/library/64484/survey_32212381.pdf and print using "control p".
2. To save your partial answers and complete the questionnaire later, click on the "Save and Continue Later" link at the top of your screen. A link to the incomplete questionnaire will be emailed to you from *SurveyGizmo.* To return to the questionnaire later, open the email from *SurveyGizmo* and click on the link. We suggest using the "Save and Continue Later" feature if there will be more than 15 minutes of inactivity while the survey is opened, as some firewalls may terminate due to inactivity.
3. To pass a partially completed questionnaire to a colleague, click on the on the "Save and Continue Later" link at the top of your screen. A link to the incomplete questionnaire will be emailed to you from *SurveyGizmo.*" Open the email from *SurveyGizmo* and forward it to a colleague.
4. To view and print your answers before submitting the survey, click forward to the page following Question No. 34. Print using "control p."
5. To submit the survey, click on "Submit" on the last page.

A successful synthesis of practices among the States requires your State's participation. Thank you for your time in completing this important questionnaire.

Now on to the survey. Please compete and submit this survey by February, 19. If you have any questions or problems related to this questionnaire, please contact Dr. Hugh McGee (703) 980-6778 or mcgeeforsafety@aol.com.

Part I. Respondent Information

Please enter the date (MM/DD/YYYY).

_____

Please enter your contact information.

First Name: _____

Last Name: _____

Title: _____

Agency/Organization: _____

Street Address: _____

City: _____

State: _____

Zip Code: _____

Email Address: _____

Phone Number: _____

Part II. Questions Related to Roadway Departure Problem Identification and Implementation Programs

NOTE: There are four questions in this Part II. For the first three, if you respond YES, then, if you have any documents-- policy or design guide, report, etc.-- that you can provide, you will be given the option to upload the file through the Browse tab, or to insert a hyperlink (URL address) in the Comment text box. You may also use text box to provide any comments.

1) Has your State prepared a Roadway Departure Safety Implementation Plan?

( ) Yes ( ) No

Insert link to Roadway Departure Safety Implementation Plan or provide comments:

_____

2) Has your State compiled and analyzed roadway departure crash data?

( ) Yes ( ) No

Insert link to roadway departure crash data report or provide comments.

_____

3) Has your State developed any Safety Performance Functions (SPFs) -- an equation used to predict the average number of roadway departure crashes per year at a location as a function of exposure and roadway characteristics ?

( ) Yes ( ) No

Insert link to Safety Performance Functions or provide comments

_____

4) Which of the programmatic implementation strategies listed below do you use to identify locations where roadway departure countermeasures should be applied (check all those that apply):

[ ] Systematic— widespread deployment of a cost-effective countermeasure at a certain road type (e.g. 2-lane rural) or location type (e.g. horizontal curve).

[ ] Hot-spot—countermeasure applied to a location which equal or exceed a determined threshold of crashes.

[ ] Systemic—countermeasure applied at locations which have certain risk factors, i.e. features and/or conditions similar to locations experiencing higher number of crashes than expected.

[ ] Other. Please explain below.

Please explain.

_____

Part III. Questions to Identify Countermeasures Being Used

NOTE: To date, 20 engineering-type countermeasures for roadway departure-type crashes have been identified. They are grouped under four categories-- traffic control device measures, pavement measures, roadside measures, and geometric design measures. The purpose of the next 20 questions is to determine if your State is using the specific countermeasure in the question. If you answer YES, you will be asked about the relative extent of its use (rarely, sometimes, or often), and given two options for providing relevant implementation policy or guideline documents: uploading the file (browse) or providing a link. Alternatively, you can comment in

the text box provided. If you answer NO, then you will be provided a dropdown list of potential reasons including an 'other' response where you can enter a text statement.

This part ends with questions related to any evaluations of the countermeasures your State has performed or any other comments you wish to make.

NOTE: Questions 5 through 24: Each countermeasure contains the same questions as shown in Question 5.

5) Edge Lines with widths greater than the standard 4 inches

( ) Yes ( ) No

How often is this countermeasure implemented?

( ) Rarely ( ) Sometimes ( ) Often

Insert link to any relevant policy or guideline, or provide comments.

_____

Why not? (Check all that apply.)

[ ] Not aware of countermeasure.

[ ] Countermeasure not proven to be cost effective.

[ ] Insufficient funding for countermeasure.

[ ] Negative public feedback.

[ ] Maintenance concerns.

[ ] Other.

Other (please explain):

_____

NOTE: The same set of questions was asked for the following countermeasures:

6) Advance pavement markings for curves such as "CURVE AHEAD" marked on the pavement

7) Speed advisory marking in lane

8) Special pavement marking to encourage speed reduction, e.g., optical speed bars

9) Dynamic curve warning systems, e.g. flashing LEDs on Chevron signs.

10) Flashing beacons on warning signs

11) Shoulder rumble strips

12) Edge line rumble stripe

13) Center line rumble strip(e)

14) Raised (profiled) thermoplastic pavement markings for center line or edge line.

15) SAFETY EDGE SM

16) Shoulder widening on curved sections

17) High friction surface treatment

18) Pavement grooving

19) Cable median barrier

20) Increase clear zone beyond minimum

21) Flatten side slope

22) Tree removal

23) Increase sight distance on curves

24) Superelevation improvement

Part III. Questions to Identify Countermeasures Being Used (cont.)

25) Is your State using any other countermeasure for roadway departure crashes not listed above? If yes, please explain in text box below, and either upload or provide a link to relevant policy or guideline documents.

( ) Yes ( ) No

Please describe countermeasure and/or provide link to documents below:

_____

26) Has your State conducted any research to evaluate the safety effectiveness, including the development of countermeasure modification factor (or function), for any of the countermeasures

listed in Questions 5 through 25. If yes, please upload document(s) or provide link to evaluation report, if documented.

( ) Yes ( ) No

Please describe research and/or provide link to documents below:

_____

27) Indicate which of the countermeasures your State is currently using that you feel needs more evaluation/research.

_____

28) Has your State conducted any research to evaluate the non-safety impacts of any of the countermeasures, such as durability, life-cycle, maintenance, etc.? If yes, provide comment in text box below.

( ) Yes ( ) No

Comment:

_____

29) Has your State experimented with any new technology designed to reduce roadway departure crashes? If yes, please provide information, indicating the technology, findings, status, or link to documentation.

( ) Yes. ( ) No

Technology, findings, status, or documentation link:

_____

Part IV. Questions Related to Vehicle-Based Technologies

30) With the advent of autonomous vehicles, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technologies, what actions is your State pursuing that would relate to use of these technologies for the prevention of roadway departure crashes? Please briefly indicate in comment box what these are and who can be contacted for a follow-up discussion.

_____

31) Autonomous vehicles rely on being able to detect the limits of their travel lane, which are now defined by pavement markings and/or raised pavement markers. What, if any, special actions are being taken by your State to ensure that the lane boundaries, defined by lane lines (for multi-lane facilities), edge line, or center line are well defined?

_____

Part V. Case Examples and Follow-up

32) The synthesis will include a few examples of how a State has implemented one or more countermeasures that were effective in reducing roadway departure crashes and/or reducing the severity of the crash that occurred. If you have an example that you would like to offer, please provided a brief statement in the box below.

_____

33) Who would be the appropriate person for the synthesis consultant to contact for further information?

First Name: _____

Last Name: _____

Phone Number: _____

Email: _____

Last Chance Comment Question

34) Are there any other issues related to the application of countermeasures to address the Roadway Departure crash problem that you would like to raise?

_____

Thank you for taking our survey. Your response is very important to us. If you have any questions or comments, please feel free to contact Hugh McGee at (703) 980-6778 or mcgeeforsafety@aol.com.

APPENDIX B

RESPONSES TO SURVEY QUESTIONNAIRE

This appendix contains 33 tables. Each table shows the responses of each state to the questions shown in Appendix A. Many of the tables provide hyperlinks to reports or websites. Clicking on the hyperlink will connect you directly to the report or website. In a few cases where clicking will not take you directly, it will be necessary to copy the URL and paste in your browser. All URLs were active when this report was submitted.

TABLE B1. States That Have Prepared a Roadway Departure Safety Implementation Plan

State	Link to RDSIP	Comment
AL	(Yes, but no further information provided)	
AZ	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-4774ee14e7acfaf63e7750d25f99e549_AZRoadway_Departure_Safety_Implementation_Plan-060812_.pdf	
CT	(Yes, but no further information provided)	
FL	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/80-7e4d4e42b6863127ef4307e1a6c28e17_FHWA_RDIP_Dec_2016.pdf http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/130-98a8ad4b677418e7882ad13ad6f8b2e3_Appendix_A_-_Florida_RD_Data_Package_and_Strategy_Matrix_2015-11-24.pdf	The attached Florida Roadway Departure Safety Plan will be updated to follow an Highway Safety Manual (EB Method) to determine locations rather than the historical crash method that was done as part of this report.
GA	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/130-dac3b16c45c01d59ace37c0d366e746e_SHSP_2015_FINAL_2015_02_23.pdf	
KY	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/79-197bfe08955bad5d99b1d6cf78ea9c62_Pages%2Bfrom%2BKYTC%2BRD%2BAction%2BPlan%2BTransmittal%2BLtr.pdf	23 U.S.C. 148(h)(4) and 23 U.S.C. 409. All documents are provided for research purposes only and is not to be disseminated within the report itself.
LA	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-9988a362d8e589b6edec9d4b6530a6e6_RDIP_LA_Draft_Final_Report_2014-03-13.docx	We are in the process of updating the Roadway Departure Improvement Plan in coordination with the FHWA under the Every Day Counts - Data Driven Safety Analysis and Focused Approach.
MI		We do not have a formal Implementation plan, but we follow the Strategic Highway Safety Plan.
MN	http://www.dot.state.mn.us/trafficeng/safety/docs/district-safety-plans-update-example.pdf http://www.dot.state.mn.us/stateaid/trafficsafety/county/ottertail-crsp-final-aug2011.pdf	Not specifically called this. We have done Trunk Highway (District) Safety Planning and County Road Safety Planning. Within these plans we have specifically identified road/lane departure
MT	http://www.mdt.mt.gov/visionzero/roads/roadway-departure.shtml	
NC	http://ncshsp.org/emphasis_areas/departure/ http://ncshsp.org/appendices/appendix-g/	

TABLE B1. States That Have Prepared a Roadway Departure Safety Implementation Plan

State	Link to RDSIP	Comment
NH		Within our Strategic Highway Safety Plan.
NV	http://www.zerofatalitiesnv.com/safety-plan-what-is-the-shsp/	Through our Lane Departures Critical Emphasis Area we have several mitigations in process, refer to the SHSP on this website.
OH	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/31-03d4456a0257cbeb0a038c8de34d7248_Technical%2BAssistance%2Bin%2Bthe%2BDevelopment%2Bof%2Ba%2BRoadway%2BDeparture%2BSafety%2BImplementation%2BPlan.pdf	
OR	http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/pages/roadway_departure.aspx	
PA	(Yes, but no further information provided)	
SC	(Yes, but no further information provided)	
TX	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-bbe538c2c90fa17b4a9ae96ebcdf241e_Systemic_Widening_Tech_Memo_.pdf	
VA	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/6-140e8a30ac0dc54c6a6fbeaf92791eb5_VA_RwD_Safety_Plan_2015-08-18.pdf	
WA		Part of WSDOT's 10-Year Capital Safety Investment Plan, Run-off the Roadway Strategies (2017, currently in draft form)
WV	(Yes, but no further information provided)	

TABLE B2 States That Have Analyzed Roadway Departure Crash Data

State	URL for Crash Data	Comments
AL	(YES, but no further information provided)	
AR	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/203-2205354e06d1056f913d01dc79d26601_Roadway_Departure.xlsx	
AZ	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-4774ee14e7acfaf63e7750d25f99e549_AZRoadway_Departure_Safety_Implementation_Plan-060812_.pdf	Contained in plan; see URL
CT	(YES, but no further information provided)	
DE	www.safety.deldot.gov	See our Strategic Highway Safety Plan at www.safety.deldot.gov
FL	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/130-317d83d2cc069782a55a5778571173c6_2009-2013_LaneDep_Fatl%26SerInj_Den1p0.pdf	
GA	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/240-9dabf701474996644dfb79c48a66ad42_RwD_Data_2016.xlsx	
HI		Accident data has been provided to our vendor that is in the process of developing a Roadway Departure Plan. Hawaii's HSIP currently is placing more emphasis on implementing corridor lane departure projects vs. hot spot type projects.
IL		We could provide samples of data trees and/or heat maps for specific counties.
IN	(YES, but no further information provided)	
KS	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/17-3b0b436607d3e09cb48e4227d476b637_Roadway_Departure.pdf	The attached file is from our latest SHSP.
KY	(Responded YES, and provided a link but restricted its presentation in the report)	
LA	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/189-1f1c516d6db56024d30651a20c649e97_Systemic_Analysis.xlsx	Pay attention to tabs. For the purposes of this synthesis, target classification, target crash type, non-collision, ADT, lane width, shoulder width, degree of curve may be of most interest. Much deliberation took place regarding how to cast the "crash net" to capture all potential roadway departure crashes. Also, an emphasis on fatalities and serious injuries provided the linkage to our SHSP.

TABLE B2 States That Have Analyzed Roadway Departure Crash Data

State	URL for Crash Data	Comments
MA	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/238-21765e27f3b8de4c7f4426dfdcf6006a_FINAL_VIEW_Statewide_LD_6_06.pdf	
ME	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/74-8f9c2d14c14ce91ab5441ea5f0515bf6_WOR_HObySpeedlmt_HCP2010to2014.xlsx	http://www.maine.gov/mdot/publications/docs/plansreports/RScorridorperfAug_2016_FINAL.pdf
MI	https://www.michigan.gov/documents/mdot/RC1612_474931_7.pdf www.michigan.gov/rumblestrips	MDOT has a High Crash program that is conducted every other year. The objective of the High Crash Program is to reduce fatalities and serious injuries on the state trunkline system in support of the Strategic Highway Safety Plan (SHSP) and the department's efforts of achieving the vision Toward Zero Deaths (TZD). MDOT also has the trunkline wet weather crash reduction program as part of the Safety Programs Unit. Pavement friction data is collected on all state trunklines by county on a three year cycle, with 1/3rd of counties tested each year. The Safety Programs Unit develops a list of locations with a friction number of less than 30 on a two year cycle. The Regions conduct a crash analysis and field review of these locations to evaluate the need for action. The individual Regions are responsible for identifying improvements and must report the results of the analysis and course of action to the Safety Programs Unit. See study of High-Tension Cable Barriers on Michigan Roadways and - Rumble Strip Program in Michigan including research, Phase I and Phase II, along with education information - www.michigan.gov/rumblestrips
MN	http://www.dot.state.mn.us/trafficeng/safety/docs/fatalrunoffroadstudy.pdf http://www.dot.state.mn.us/trafficeng/safety/docs/fatalheadonstudy.pdf	Most of our safety plans go thru an analysis breaking down road departure. We have specifically looked into greater detail of this issue.
MS		We don't have a statewide analysis. We do this through data mining along a route or in a region. We've previously requested assistance with the development of an RDSIP, but, to date, we have not been selected.
MT		We are using this study to develop our HSIP projects. Call for details if you need more info.
NC		See links above
ND		http://www.dot.nd.gov/divisions/safety/docs/crash-summary.pdf
NE	(YES, but no further information provided)	
NH	(YES, but no further information provided)	

TABLE B2 States That Have Analyzed Roadway Departure Crash Data

State	URL for Crash Data	Comments
NV	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/79-0738016682dfe88e2bea1e3a17c35087_Scanned%2Bfrom%2Ba%2BXerox%2BMultifunction%2BPrinter.pdf	
NY		NY studied lane departure crashes in a systemic study pilot. Several risk factors were identified including rural roads with 2 lanes and 55 mph or greater speed limits. AADT between 3,999 and 5,000 and curves with a low radius were also determined to be risk factors. Lane departures will be one of the emphasis areas in NY's updated Strategic Highway Safety Plan. One of the actions noted in the SHSP is to develop a lane departure action plan.
OH	http://www.dot.state.oh.us/Divisions/Planning/ProgramManagement/HighwaySafety/SHSP/Safety_Fact_Sheets/Roadway%20Departure%20Related.pdf	
OR		We have a tool that can analyze for Roadway Departure Crashes called OASIS a network screening tool an online tool similar to our Safety Priority Index System (SPIS)
PA	(YES, but no further information provided)	
SC	(YES, but no further information provided)	
TX	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-a59de65b2d1310d68c6913c37ce4af90_Roadway_and_Lane_Departure_SHSP.docx	
UT		We have developed and use a hierarchical bayesian crash model to screen, diagnose, select, appraise, prioritize and evaluate statewide highway safety projects. It does not produce SPF's that we can upload.
VA	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/221-0791c5cbf43d8c472f15a34cfdfc3446_RD_Crash_Victims_by_Routes_in_Each_County.xlsx	
VT	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/238-97f33f69c02e360f430ea3d7afd82ebf_2016-2020_SHSP_Data_Lane_Departure.pdf	The attached file is what was done for the Strategic Highway Safety Plan update (SHSP)
WA		Assessed in WSDOT's Collision Analysis Corridor and Collision Analysis Location reviews every two years.
WI	(YES, but no further information provided)	
WV	(YES, but no further information provided)	

TABLE B3. States That Have Developed Safety Performance Functions for Roadway Departure Crashes

State	URL for file containing SPFs	Comments
AL	(Yes but no further information provided)	
CO	https://www.codot.gov/library/traffic/safety-crash-data/safety-analysis-information	SPF's are for total crashes and not specific crash types like roadway departures. However, normative baselines with expected percentage of roadway departure crashes per type of facility can be applied to SPF to estimate expected number of roadway departure crashes. Normative baselines also included in the link.
IL	https://www.ideals.illinois.edu/bitstream/handle/2142/45952/FHWA-ICT-10-066.pdf?sequence=2&isAllowed=y	
IN		The Joint Transportation Research Program (JTRP), a cooperative research relationship between the Indiana DOT and Purdue University, principally through the Center for Road Safety (CRS) in West Lafayette, Indiana, has developed SPFs for a range of crash severities and types. Those SPFs, to the best of my knowledge, are not contained in a single/central document but in a series of research publications from JTRP/CRS over the past half dozen years or so. Among the models/tools developed through that research relationship for INDOT use that include SPFs are HAT (Hazard Analysis Tool) and SNIP.
KY	See document from #2. (note: document restricted for public use)	
MI		Michigan Urban Trunkline Intersections Safety Performance Functions (SPFs) Development and Support - https://www.michigan.gov/documents/mdot/RC1628_497550_7.pdf The rural trunkline SPF's will be completed in 2017.
MT		We have SPF for the locations shown in the report but are currently for internal use.
SC	(Yes but no further information provided)	
TX	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-d2f79539c89ed9b53df2a3b99784ea61_0-4703-P2.pdf	
VA	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/94-e04f6e2b4d08f742f9a125bf41e97fea_VHB_Virginia_Statewide_Safety_Performance_Functions_20150616.xlsx	We have Part B Total and F+I SPFs for all segment and intersection site sub-types on the VDOT. That is no urban (city, Arlington and Henrico Co SPFs as we are just collecting the needed LRS) All are documented in reports on VTRC website with the equations in the attached XLS file used to develop CMFs for SMART SCALE

TABLE B4. Programmatic Implementation Strategies Used by States

State	Systematic	Hot-spot	Systemic	Other
AK	✓	✓	✓	
AL	✓	✓	✓	Sites identified through network screening and further refined through road safety audits.
AR		✓	✓	
AZ	✓		✓	
CO		✓	✓	
CT	✓	✓	✓	
DE	✓	✓	✓	
FL	✓	✓	✓	
GA		✓	✓	
HI	✓		✓	
ID		✓		
IL	✓	✓	✓	
IN	✓	✓	✓	
KS	✓	✓	✓	
KY	✓	✓	✓	
LA		✓	✓	Some low-cost countermeasures have been incorporated into our standards (i.e. rumble strips on certain classifications of road with a certain shoulder width).
MA	✓	✓	✓	
MD	✓	✓		
ME		✓	✓	
MI	✓	✓	✓	
MN	✓	✓	✓	County Road Safety Audits also once prescribed preferred locations to implement. We have not used this technique in a few years.
MS	✓	✓	✓	
MT		✓	✓	
NC	✓	✓	✓	
ND	✓	✓	✓	
NE	✓	✓	✓	
NH	✓	✓		
NV	✓	✓	✓	we use Safety Management Plans which looks at segments of roads with "Hot Spots", this approach applies consistent improvements through out the length of the chosen corridor.
NY	✓	✓	✓	
OH	✓	✓	✓	
OR	✓		✓	
PA		✓	✓	
SC	✓	✓	✓	
SD	✓	✓		
TX	✓	✓	✓	
UT	✓	✓	✓	We use usRAP as a systemic safety analysis tool to characterize crash risk.

TABLE B4. Programmatic Implementation Strategies Used by States

State	Systematic	Hot-spot	Systemic	Other
VA		✓	✓	
VT	✓	✓		
WA	✓	✓	✓	
WI	✓	✓	✓	Some of our policy to identify locations can be found here: http://wisconsindot.gov/rdwy/fdm/fd-11-45.pdf
WV		✓	✓	

TABLE B5. States' Practice for Use of Wide Edge Lines

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Rarely							
AL	Yes	Often							
AR	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-5290e4b0b7eb1187c5ff66de3a2949a3_Pavement_Markings_Practices.pdf						
AZ	Yes	Often							
CO	No					✓		✓	
CT	No				✓			✓	
DE	Yes	Sometimes	No policy or guidance exists. This countermeasure is applied on a case-by-case basis.						
FL	Yes	Often	Per FDOT Index 17346, Edge Lines are 6 inches http://www.fdot.gov/roadway/DS/18/IDx/17346.pdf						
GA	No			✓					
HI	Yes	Sometimes	Used to emphasize lateral obstructions.						
ID	Yes	Rarely	Used 8" lines as a pilot at one location and 6" lines at another per an RSA recommendation.						
IL	Yes	Sometimes							
IN	Yes	Sometimes	Wider than 4-inch edge lines are generally reserved for freeways.						
KS	Yes	Often	Our DOT standard is 6".						

TABLE B5. States' Practice for Use of Wide Edge Lines

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
KY	No				✓				We do use 6 inch lines on our Interstate and Parkways (and a few other "major" routes), but they are not limited to edgelines and are considered to be a "standard" installation.
LA	Yes	Sometimes	We are in the process of implementing 6" edge lines in combination with enhanced signing and HFST on curves identified through the systemic analysis as provided previously.						
MA	Yes	Often	http://www.massdot.state.ma.us/Portals/8/docs/traffic/MassMUTCD20120409.pdf Page 63 of Massachusetts Amendments to MUTCD states all State highway use 6" for normal longitudinal. Next Amendment revision will include normal longitudinal lines on ALL roads to be 6" unless justified.						
MD	Yes	Often	Please refer to section 3A.06 in the Maryland MUTCD. 5" line is the standard on state owned and maintained roadways.						
ME	Yes	Rarely							

TABLE B5. States' Practice for Use of Wide Edge Lines

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MI	Yes	Often	The Texas Transportation Institute (TTI) found that in Michigan, 6 inch wide edge line markings produced reductions for all crash types, including a 24.6 percent reduction in fatal and injury crashes, a 39.5 percent reduction for crashes at night and a 33.2 percent reduction in wet crashes at night on rural two-lane trunklines. TTI's review showed a benefit-cost ratio for wide edge lines to be $33 to $55 for each $1 spent. With an estimated increased cost of $840,000 per year the safety benefit is $27.8 to $46.2 million per year. In addition, the research showed a reduction of total crashes of approximately 19 to 27 percent and single vehicle wet crashes by 66 to 74 percent.						
MN	Yes	Sometimes	Mostly completed with HSIP funding on locations identified as higher risk thru safety planning processes.						
MS	Yes	Often	We universally use 6" stripe. Standard Drawing PM-1 (Page 7 of the PDF),						
			http://sp.mdot.ms.gov/RoadwayDesign/Standard%20Drawings/Roadway_Standards_Active_1998.pdf						

TABLE B5. States' Practice for Use of Wide Edge Lines

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MT	Yes	Rarely	spot locations where the safety analysis shows this feature might be an effective countermeasure.						
NC	Yes	Sometimes							
ND	No								Plan on implementing wider edge lines in the near future.
NE	Yes	Often							
NH	No				✓				Rather than "Countermeasure not proven to be cost effective", my response would be "Not convinced that countermeasure is cost effective"
NJ	Yes	Sometimes							
NV	Yes	Rarely							
NY	Yes	Rarely							
OH	Yes	Often							
OR	No								Don't believe wider lines to have the advantage claimed also looks makes the shoulder look like a bike lane
PA	Yes	Sometimes							
SC	Yes	Sometimes							
SD	Yes	Rarely							
TX	Yes	Rarely							
UT	No								We are currently creating a research project that will test 6" lines in 2017.

TABLE B5. States' Practice for Use of Wide Edge Lines

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
VA	Yes	Sometimes	Policy on Interstates, some have extended to all freeways (Primary system). Used in spot locations (curves, bridges etc) in one district, others a are systematic or corridor based on Primary roadways.						
VT	Yes	Rarely	Wider lines are used on the interstate. I am not aware that wider lanes have been used on two-lane roads to prevent crashes.						
WA	No				✓				
WI	No					✓			The Wisconsin Department of Transportation (WisDOT) is currently prioritizing nighttime reflectivity for edge lines.
WV	Yes	Often							

TABLE B6 States' Practices for Use of Advance Pavement Markings

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	No							✓	
AL	Yes	Rarely							
AR	Yes	Rarely	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/238-c5660d1e16d99b4d28325c138a0e728d_TRC_1305_FINAL_REPORT.pdf We have tried this countermeasure for research.						
AZ	Yes	Often							
CO	No					✓		✓	
CT	No							✓	
DE	No							✓	
FL	Yes	Rarely							
GA	No								
HI	No								Preference with warning signs
ID	No							✓	I'm not aware of any done on Idaho state routes. Maintenance of the markings may be a challenge given the increasing demands on maintenance forces.
IL	No			✓				✓	
IN	No								
KS	Yes	Rarely	Based on an engineering study.						
KY	Yes	Rarely	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/202-53d6251e02c786292095ea0eaadc2682_Drawings.pdf Experimental application.						

TABLE B6 States' Practices for Use of Advance Pavement Markings

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
LA	No							✓	
MA	No								
MD	Yes	Rarely							
ME	No							✓	
MI	No							✓	
MN	No				✓			✓	
MS	No								We will be deploying this countermeasure in an upcoming project, treating curves along a rural route in SE Mississippi.
MT	No							✓	
NC	No							✓	Concerned about vehicles and motorcycles sliding on markings, particularly if they are long life markings such as thermoplastic.
ND	No								
NE	No							✓	
NH	No				✓	✓		✓	
NJ	No								
NV	No							✓	Don't use this strategy yet but will look into it when we start our Curve Improvement project next year
NY	Yes	Rarely							
OH	No						✓		In lane pavement markings are not used in Ohio.
OR	No				✓			✓	Although some positive effect it has a negative maintenance concerns

TABLE B6 States' Practices for Use of Advance Pavement Markings

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
PA	No								
SC	No								Other countermeasures are used instead such as doubling up signing, fluorescent sheeting, sign mounted flashers
SD	No								
TX	Yes	Rarely							
UT	No							✓	
VA	Yes	Rarely	A couple of pilots in VA that have not been replicated and may be warn away.						
VT	No							✓	Aware of countermeasure but not part of our current practice.
WA	No				✓				
WI	No							✓	Signs can be more effective with retro-reflectivity.
WV	Yes	Often							

TABLE B7. States' Practice for Use of Speed Advisory Pavement Markings

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	No							✓	
AL	No							✓	
AR	Yes		http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-a6d988cd1a4996d5f69aca49974811d3_Pavement_Markings_Practices.pdf						
AZ	No			✓					
CO	No					✓		✓	
CT	No							✓	
DE	No							✓	
FL	Yes	Rarely							
GA	Yes	Rarely							
HI	No								Preference with regulatory signs
ID	No							✓	I'm not aware of any done on Idaho state routes. Maintenance of the markings may be a challenge given the increasing demands on maintenance forces.
IL	No			✓				✓	
IN	Yes	Rarely							
KS	No								

TABLE B7. States' Practice for Use of Speed Advisory Pavement Markings

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
KY	No								Considered as part of in-lane curve warning markings, but decided the use of "SLOW" would allow uniformity and to provide the ultimate intent of warning of the potential issue.
LA	No							✓	
MA	No							✓	
MD	Yes	Rarely							
ME	Yes	Rarely							
MI	No							✓	
MN	No				✓			✓	
MS	No								Since motorists tend to drive to their comfort level, I'm doubtful this countermeasure would be effective in Mississippi.
MT	No							✓	
NC	No							✓	Concerned about vehicles and motorcycles sliding on markings, particularly if they are long life markings such as thermoplastic.
ND	No							✓	
NE	No							✓	
NH	No				✓	✓		✓	
NJ	Yes	Rarely							

TABLE B7. States' Practice for Use of Speed Advisory Pavement Markings

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
NV	Yes	Rarely	used rarely where speed is a factor in crashes.						
NY	Yes	Rarely							
OH	No						✓		In lane pavement markings are not used in Ohio.
OR	No				✓			✓	
PA	Yes	Rarely							
SC	No								Other countermeasures are used instead such as doubling up signing, fluorescent sheeting, sign mounted flashers
SD	No								
TX	Yes	Rarely							
UT	No								
VA	No					✓		✓	
VT	No							✓	Not part of our current practice.
WA	No				✓				
WI	No							✓	Signs can be more effective with retro-reflectivity.
WV	No					✓			

TABLE B8. States' Practices for Use of Special Pavement Markings for Speed Reduction

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Rarely							
AL	Yes	Rarely							
AR	Yes	Rarely	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/99-a1d102816252f6ddefae26c420389639_TRC_1305_FINAL_REPORT.pdf We have tried optical speed bars in a research project.						
AZ	No			✓					
CO	No					✓		✓	
CT	No								
DE	Yes	Rarely	We utilize the speed reduction markings shown in the MUTCD. We have installed these at three locations throughout the state with mixed results.						
FL	No								Countermeasure showed an initial change in driver behavior (speed reduction) but not long term.
GA	Yes	Rarely							
HI	No								Use alternate countermeasures such as speed feedback signs
ID	No								I'm not aware of any done on Idaho state routes. Maintenance of the markings may be a challenge given the increasing demands on maintenance forces.
IL	Yes	Rarely							

TABLE B8. States' Practices for Use of Special Pavement Markings for Speed Reduction

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
IN	No								
KS	Yes	Rarely	We've experimented with optical speed bars with hit and miss success. We've also experimented with elongated pavement signing.						
KY	No				✓				Tried many years ago. Wasn't shown to be effective.
LA	Yes	Rarely	I believe there was a pilot project in one of our Districts but have not seen it implemented since.						
MA	Yes	Rarely	None available, but have used for Safe Routes to Schools projects.						
MD	Yes	Rarely	We have installed these on a few corridors that have had a history of road departure crashes. It is not a widespread practice.						
ME	Yes	Rarely							
MI	Yes	Rarely							
MN	No				✓			✓	
MS	Yes	Rarely	This is a spot treatment that has been used rarely in Mississippi. I believe the ELCSI Pooled Fund Study determined these to have limited safety benefit, so we do not push for their installation.						
MT	Yes	Rarely	used thermoplastic transverse rumble strips; used at spot locations where the crash history/close proximity to homes.						
NC	Yes	Rarely							

TABLE B8. States' Practices for Use of Special Pavement Markings for Speed Reduction

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
ND	No								Hope to implement in the near future. Need to get buy in from department staff.
NE	No							✓	
NH	No					✓		✓	
NV	No								
NY	Yes	Rarely							
OH	Yes	Rarely							
OR	No				✓				Tried and did not seem to be effective
PA	Yes	Rarely							
SC	No								
SD	No								
TX	Yes	Rarely							
UT	No							✓	
VA	Yes	Rarely	Pilots in NoVA Fairfax two-lane secondary (shoulder) and four-lane undivided US 460 towards Suffolk (cross lanes). Probabaly wont be replaced with next overlay due to limited success on speed reductions						
VT	Yes	Rarely	We did a research project: http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/AOT_DynamicStripingInFourTownsAlongVTRoute30FinalReport2007.pdf						
WA	Yes	Rarely							
WI	No							✓	
WV	No				✓				

TABLE B9. States's Practices for Use of Dynamic Curve Warning Systems

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	No							✓	
AL	Yes	Rarely							
AR	Yes	Rarely	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/238-d609f8e79b8c8ccd3b56efe2aeb18a9a_TRC_1305_FINAL_REPORT.pdf We have tried LED curve warning signs as a research project.						
AZ	No								
CO	Yes	Rarely	https://www.youtube.com/watch?v=5yClKNiuDDc						
CT	No					✓		✓	
DE	No				✓			✓	
FL	Yes	Sometimes							
GA	No								
HI	No								Have used Stop Signs with flashing LEDs
ID	Yes	Sometimes	Placed on advance curve ahead signs. Not sure if they can be called "dynamic", most are solar powered and that constantly flash.						
IL	Yes	Rarely							
IN	Yes	Sometimes							
KS	Yes	Rarely	Based on an engineering study.						
KY	No							✓	
LA	Yes	Rarely							
MA	No								

TABLE B9. States's Practices for Use of Dynamic Curve Warning Systems

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MD	Yes	Rarely	We generally have used these for commercial vehicles at problematic curves with over height and or speed detection. We have also installed beacons actuated based on vehicle speed at certain curves with high crash history.						
ME	Yes	Rarely							
MI	No							✓	
MN	No				✓				
MS	No							✓	We will deploy these on the aforementioned curve project in question #6. Power source and upkeep of the devices are typically a concern with these treatments, as most district will shy away from the use of solar devices, as they tend to get stolen.
MT	Yes	Sometimes							
NC	Yes	Rarely							
ND	Yes	Rarely							
NE	No					✓			

TABLE B9. States's Practices for Use of Dynamic Curve Warning Systems

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
NH	No					✓			Would want to identify criteria for consideration of this countermeasure, otherwise, they would be requested at any location where there was a serious crash, regardless of the cause.
NV	Yes	Rarely	we have had one project where we installed dynamic warnings that alert a speeding motorist. we will be looking into more locations when we roll out our Curve Improvement Program next year.						
NY	Yes	Sometimes							
OH	Yes	Rarely							
OR	Yes	Rarely							
PA	Yes	Sometimes							
SC	No								
SD	No								
TX	Yes	Sometimes							
UT	Yes	Rarely							
VA	Yes	Rarely	Started on I-81 curves with good results. Presently testing on lower volume Primary (VTTI study).						

TABLE B9. States's Practices for Use of Dynamic Curve Warning Systems

State	Use	Frequency	URL for relevant file or comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
VT	Yes	Rarely	To my knowledge, we installed a dynamic large arrow at one location as part of a bridge project. At this site, the majority of the crashes were during evening hours with drivers that were unfamiliar with the roadway alignment (down the hill and around the corner with the bridge right after the curve.						
WA	Yes	Rarely							
WI	Yes	Rarely	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/133-504626c2dd63b28b65fc1fad9a095826_02-01-08.pdf						
WV	No							✓	

TABLE B10. States' Practices for Use of Flashing Beacons on Warning Signs

State	Use	Frequency	URL for relevant file or cmment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Sometimes							
AL	Yes	Sometimes							
AR	Yes	Rarely							
AZ	Yes	Rarely							
CO	Yes	Sometimes							
CT	Yes	Rarely							
DE	Yes	Sometimes	No guidelines exist. Used on a case-by-case basis.						
FL	Yes	Sometimes							
GA	Yes	Often							
HI	Yes	Sometimes							
ID	Yes	Sometimes	on advanced curve and intersection ahead signs.						
IL	Yes	Sometimes							
IN	Yes	Sometimes							
KS	Yes	Sometimes	Based on an engineering study.						
KY	Yes	Sometimes	See Section TO 610 in: http://transportation.ky.gov/Organizational-Resources/Policy%20Manuals%20Library/Traffic%20Operations.pdf						
LA	Yes	Sometimes							
MA	Yes	Rarely	none available						

TABLE B10. States' Practices for Use of Flashing Beacons on Warning Signs

State	Use	Frequency	URL for relevant file or cmment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MD	Yes	Rarely	These are installed on a case by case basis after a thorough engineering study. We have some that flash all the time and others that are actuated based on traffic factors/conditions.						
ME	Yes	Rarely							
MI	No							✓	
MN	Yes	Sometimes							
MS	Yes	Sometimes	This is a spot treatment that is used when standard traffic control devices have proven to be ineffective in solving the problem.						
MT	Yes	Often							
NC	Yes	Sometimes							
ND	Yes	Sometimes							
NE	Yes	Often							
NH	Yes	Rarely							
NV	Yes	Often	we install solar powered flashing red stop beacons on rural intersections.						
NY	Yes	Often							
OH	Yes	Rarely							
OR	Yes	Rarely	When the sign itself has been ineffective and power is available it is considered						
PA	Yes	Sometimes							

TABLE B10. States' Practices for Use of Flashing Beacons on Warning Signs

State	Use	Frequency	URL for relevant file or cmment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
SC	Yes	Sometimes							
SD	Yes	Often							
TX	Yes	Often							
UT	Yes	Rarely							
VA	Yes	Rarely	More prevalent for intersection warning, but have seen some applications on ramps (roll-over) and curves.						
VT	Yes	Sometimes	Usually considered at hot spots.						
WA	Yes	Often							
WI	Yes	Rarely	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/31-b7a06d6ba58ee7f73d6b7190c344b851_04-05-01.pdf						
WV	Yes	Often							

TABLE B11. States' Practices for Use of Shoulder Rumble Strips

State	Use	Frequency	URL for relevant file or Comment
AK	Yes	Often	
AL	Yes	Often	
AR	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-03e6f8c13bd0b0c762e58d5533dec020_Policy_for_the_Use_of_Rumble_Strips_20120403.pdf
AZ	Yes	Often	
CO	Yes	Often	
CT	Yes	Often	
DE	Yes	Often	http://www.deldot.gov/Publications/manuals/dgm/pdfs/1-25_safety_edge_revised.pdf
FL	Yes	Often	
GA	Yes	Often	
HI	Yes	Often	HDOT designers have been encouraged to implement more of this since 2006. It is becoming much more utilized now and we hope to increase installation with a new Milled Rumble Strip Guideline.
ID	Yes	Often	Typically any major roadway new or reconstruction would include shoulder rumbles in rural locations. Also have had projects programmed specifically for rumble installations
			http://apps.itd.idaho.gov/apps/StandardDrawings/c2a_0514.pdf
IL	Yes	Often	
IN	Yes	Often	
KS	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/70-1e49838614762d902e6b053140be9944_Scanned_Rumble_Strip_Policy_071307.pdf
KY	Yes	Often	http://transportation.ky.gov/Highway-Design/Standard%20Drawings%20%20Sepias%20PDFs%202016/Sepia%20005.pdf
			http://transportation.ky.gov/Highway-Design/Standard%20Drawings%20%20Sepias%20PDFs%202016/Sepia%20007.pdf
			http://transportation.ky.gov/Highway-Design/Standard%20Drawings%20%20Sepias%20PDFs%202016/Sepia%20008.pdf
LA	Yes	Often	http://wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Engineering/Standard_Plans/Pages/default.aspx?RootFolder=%2FInside%5FLaDOTD%2FDivisions%2FEngineering%2FStandard%5FPlans%2FSpecial%20Details%2FRumble%20Strips&FolderCTID=0x012000B45DF4ABE71813419EF4AF62EBF6A9F3&View={818530E6-561D-4F7C-A684-91AEF628795A}
MA	Yes	Often	https://www.massdot.state.ma.us/Portals/8/docs/EngineeringDirectives/2014/E-14-004.pdf
MD	Yes	Often	https://www.roads.maryland.gov/OOTS/GuidelinesApplRumbleStripsStripes.pdf
ME	Yes	Rarely	There are installed on both edges of interstate roads, rare use on secondary.
			www.michigan.gov/rumblestrips

TABLE B11. States' Practices for Use of Shoulder Rumble Strips

State	Use	Frequency	URL for relevant file or Comment
MI	Yes	Often	To determine the overall effectiveness of the effort Wayne State University completed the 'Evaluation of Non-Freeway Rumble Strip-Phase II' for the department. The safety performance analysis indicated statistically significant reductions in the range of 47 percent in all types of target crashes (head-on, sideswipe opposite and run-off-theroad left) after centerline rumble strips were installed. Researchers identified 2,488 target crashes in the three years before installation of centerline rumble strips and 1,306 in the three years after installation. They noted a 43 percent to 55 percent reduction in head-on, sideswipe opposite and single-vehicle run off the roadway crashes. Overall fatal and injury crashes were cut in half, with a 51 percent reduction in fatal crashes and a 47 percent reduction in injury crashes. The economic analysis produced equally significant results. Researchers estimated a cost benefit of nearly $80 million over three years as a result of the crash reductions from centerline rumble strip installation. The estimated centerline rumble strips benefit-to-cost ratios on two-lane rural highways is estimated to be between 58:1 and 18:1.
MN	Yes	Often	Required on most rural projects. http://dotapp7.dot.state.mn.us/edms/download?docId=1463482
MS	Yes	Rarely	Mississippi routes typically do not have full width shoulders. Those locations that are paved with OGFC typically have shoulder rumble strips. All other locations have edge line rumble stripes.
MT	Yes	Often	http://www.mdt.mt.gov/other/webdata/external/cadd/design_memos/2015-07-08_RUMBLE_STRIP-4.pdf
NC	Yes	Often	
ND	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/80-a3c29efefe4ec2ddff34f684b858ffb1_rumble_strips_criteria_for_installation.pdf
NE	Yes	Often	
NH	Yes	Often	Often used on divided highways, seldom used on conventional roads due to noise complaints.
NV	Yes	Rarely	our standard is rumble Stripe but occasionally due to construction sequencing, the rumble goes in after the lane stripe is placed.

TABLE B11. States' Practices for Use of Shoulder Rumble Strips

State	Use	Frequency	URL for relevant file or Comment
NY	Yes	Often	SHARD-Eligible Highway Sections: •Lane Width: The travel lane width after any restriping should be 11' (3.3 m) or more. •Shoulder Width: To provide for adequate bicycle maneuvering beyond the rumble strip, rumble strips should not be installed on shoulders under 6' (1.8 m) in width since they do not provide width for the offset to the rumble strip, the 12" (300 mm) rumble strip width, and a remaining 4' (1.2 m) paved shoulder for cyclists. Exceptions may be made where: o There is an accessible, parallel bicycle facility within 200' (60 m) o There is a run-off-the-road crash problem based on a site-specific crash analysis, or the facility prohibits cycling •Length: The total quantity of SHARDs in a project is 5,000' (1,500 m) or more. Because of the cost of mobilizing the equipment to mill in the SHARDs, projects that would result in the total placement of less than 5,000' (1,500 m) may be exempted. Milling work that extends beyond the limits of the paving project should be considered. •Speed: The posted speed is 50 mph (80 km/h) or greater. The likelihood of a severe injury or fatality increases dramatically in collisions of 45 mph (70 km/h) or greater. 50 mph (80 km/h) was chosen since some reduction in speed is anticipated when a vehicle leaves the road prior to a collision with a fixed object. •Volume: A current AADT of 2,000 vpd or more. As traffic volumes decrease, the likelihood of collisions decreases, with or without the use of SHARDs. •Roadway Width: The combined width of the lane(s) and shoulder, in each direction, must be at least 17' (5.2 m). •Longevity: Shoulders are not likely to be repaved within 3 years of the SHARDs placement. •Exceptions: The requirement to install SHARDs may be waived by the Deputy Chief Engineer (Design) for eligible highway segments that do not have a higher than average history of run-off-the-road crashes and are located within 1,000 feet of a residential neighborhood.
OH	Yes	Often	See 1415 RUMBLE STRIPS (INCLUDING STRIPES) IN THE ROADWAY in URL below http://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/traffic/TEM/Pages/default.aspx
OR	Yes	Often	We have an interim policy but right now it is interim because of noise concerns, working on mumble strips testing
PA	Yes	Sometimes	
SC	Yes	Often	
SD	Yes	Often	http://www.sddot.com/business/design/docs/rd/rdmch07.pdf
TX	Yes	Often	
UT	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/89-bfc429d931d498bb77b519342034965e_UDOT_Ruble_Strip_Std_Dwgs_2017.pdf Standard drawings are attached.
VA	Yes	Sometimes	Policy to install on rural limited access and have on some urban limited access roadways. Having difficulty making more systemic or systematic due to noise concerns (many residents along VA Primary and Secondary's) About to release new memo to match new 2016 standards (we are also piloting MNDOT sinusoidal - mumble - design). http://www.extranet.vdot.state.va.us/locdes/electronic_pubs/iim/IIM212.pdf http://www.extranet.vdot.state.va.us/LocDes/Electronic_Pubs/2016_Road%20and%20Bridge/2016%20Road%20and%20Bridge_TOC%20Section%20300.pdf
VT	Yes	Sometimes	On the interstate system
WA	Yes	Often	
WI	Yes	Often	http://wisconsindot.gov/rdwy/fdm/fd-11-15.pdf

TABLE B11. States' Practices for Use of Shoulder Rumble Strips

State	Use	Frequency	URL for relevant file or Comment
WV	Yes	Often	

TABLE B12. States' Practices for Use of Edge Line Rumble Strip

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Rarely							
AL	Yes	Sometimes							
AR	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-056655a6be641373e16dd8a3dbc6d08b_Policy_for_the_Use_of_Rumble_Strips_20120403.pdf						
AZ	Yes	Often							
CO	No								
CT	No								
DE	Yes	Often	http://www.deldot.gov/information/pubs_forms/manuals/dgm/pdf/memo_1-18_rumble_strips.pdf						
FL	Yes	Often	http://www.fdot.gov/roadway/Bulletin/RDB15-03.pdf						
GA	Yes	Often							
HI	Yes	Rarely	Used when shoulder width insufficient for Milled Rumble Strip						
ID	Yes	Rarely	some concerns over conflicts/interactions with bicyclists. http://apps.itd.idaho.gov/apps/StandardDrawings/c2a_0514.pdf						
IL	No						✓	✓	

TABLE B12. States' Practices for Use of Edge Line Rumble Strip

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
IN	Yes	Often	In combination or separately, edge-line and centerline rumble stripE treatment is now in place on approximately 700 miles of INDOT-jurisdictional roads.						
KS	No							✓	
KY	Yes	Often	http://transportation.ky.gov/Highway-Design/Standard%20Drawings%20%20Sepias%20PDFs%202016/Sepia%20006.pdf						
LA	Yes	Sometimes	http://wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Engineering/Standard_Plans/Pages/default.aspx?RootFolder=%2FInside%5FLaDOTD%2FDivisions%2FEngineering%2FStandard%5FPlans%2FSpecial%20Details%2FRumble%20Strips&FolderCTID=0x012000B45DF4ABE71813419EF4AF62EBF6A9F3&View={818530E6-561D-4F7C-A684-91AEF628795A}						
MA	Yes	Rarely	none available						
MD	Yes	Sometimes	Please see the previous provided link.						
ME	Yes	Rarely	http://www.maine.gov/mdot/edi/docs/2016/rumblestrippolicy.pdf						

TABLE B12. States' Practices for Use of Edge Line Rumble Strip

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
ME	Yes	Rarely	http://www.maine.gov/mdot/edi/docs/2016/rumblestripdetailsheet.pdf						
MI	No								Noise concerns.
MN	Yes	Sometimes	Narrow shoulders may be exempted on some projects. See Tech Memo:						
			http://dotapp7.dot.state.mn.us/edms/download?docId=1463482						
MS	Yes	Often	http://sp.mdot.ms.gov/RoadwayDesign/Design%20Memos/2004-04-19.pdf						
MT	No							✓	
NC	Yes	Sometimes							
ND	Yes	Often	See Number 11.						
NE	Yes	Often							
NH	Yes	Rarely							
NV	Yes	Often	standard practice for all rural paving projects						
NY	No								
OH	Yes		See 1415 RUMBLE STRIPS (INCLUDING STRIPES) IN THE ROADWAY in URL below						
			http://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/traffic/TEM/Pages/default.aspx						

TABLE B12. States' Practices for Use of Edge Line Rumble Strip

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
OR	Yes	Often	Same as above and we really like this one because of the added benefit of improved visibility of striping						
PA									
SC	Yes	Often							
SD	Yes	Often	http://www.sddot.com/business/design/docs/rd/rdmch07.pdf						
TX	Yes	Often							
UT	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/89-8ee34e5e58710b5944ecfdfb7166b853_UDOT_Ruble_Strip_Std_Dwgs_2017.pdf Standard drawings are attached.						
VA	No							✓	
VT	No						✓	✓	Bicyclist concerns
WA	No								WSDOT policy is offset of edge line.
WI	Yes	Rarely	WisDOT interpreted this question as Edge line rumble STRIPES. One reason why it is rarely used is due to negative public feedback (noise issues).						
			http://wisconsindot.gov/rdwy/fdm/fd-11-15.pdf						
WV	Yes	Often							

TABLE B13. States' Use of Center Line Rumble Strip

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Rarely							
AL	No							✓	Attempting to implement as part of the statewide roadway departure crash reduction program.
AR	Yes	Sometimes	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/238-2e4a925744c375d502d18eba327c74cd_Policy_for_the_Use_of_Rumble_Strips_20120403.pdf						
AZ	Yes	Sometimes							
CO	Yes	Often							
CT	Yes	Rarely							
DE	Yes	Often	http://www.deldot.gov/information/pubs_forms/manuals/dgm/pdf/memo_1-18_rumble_strips.pdf						
FL	Yes	Often							
GA	Yes	Often							
HI	Yes	Often	HDOT designers have been encouraged to implement more of this since 2006. It is becoming much more utilized now and we hope to increase installation with a new Milled Rumble Strip Guideline. CMRS is installed more often than SMRS.						
ID	Yes	Sometimes	http://apps.itd.idaho.gov/apps/StandardDrawings/c2c_0911.pdf						
IL	Yes	Sometimes							
IN	Yes	Often							
KS	Yes	Often	See attached policy for shoulder rumble strips; it covers both.						
KY	Yes	Often	http://transportation.ky.gov/Highway-Design/Standard%20Drawings%20%20Sepias%20PDFs%202016/Sepia%20002.pdf						
			http://transportation.ky.gov/Highway-Design/Standard%20Drawings%20%20Sepias%20PDFs%202016/Sepia%20003.pdf						

TABLE B13. States' Use of Center Line Rumble Strip

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
			http://transportation.ky.gov/Highway-Design/Standard%20Drawings%20%20Sepias%20PDFs%202016/Sepia%20004.pdf						
LA	Yes	Often	http://wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Engineering/Standard_Plans/Pages/default.aspx?RootFolder=%2FInside%5FLaDOTD%2FDivisions%2FEngineering%2FStandard%5FPlans%2FSpecial%20Details%2FRumble%20Strips&FolderCTID=0x012000B45DF4ABE71813419EF4AF62EBF6A9F3&View={818530E6-561D-4F7C-A684-91AEF628795A}						
MA	Yes	Rarely	Used in a few test locations						
MD	Yes	Sometimes							
ME	Yes	Sometimes	See Table B12						
MI	Yes	Often	www.michigan.gov/rumblestrips						
MN	Yes	Sometimes	Required on most rural projects, either shoulder or centerline. http://dotapp7.dot.state.mn.us/edms/download?docId=1463482						
MS	Yes	Rarely	Most districts have concerns about the reduced life span of the centerline pavement joint with CLRS. Districts typically prefer when this treatment is used that HSIP funds cover an overlay, as well, which is cost prohibitive.						
MT	Yes	Often	http://www.mdt.mt.gov/other/webdata/external/cadd/design_memos/2015-07-08_RUMBLE_STRIP-4.pdf						
NC	Yes	Sometimes							
ND	Yes	Often	See Tables B11 and B12.						
NE	Yes	Often							
NH	Yes	Sometimes							
NV	Yes	Often	standard practice for all rural 2 lane roadways.						

TABLE B13. States' Use of Center Line Rumble Strip

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
NY	Yes	Often	CARDs are required in all D Contract paving work on CARD-eligible highway segments. CARD-Eligible Highway Sections: •Pavement: Pavement surface score is 7 or better. •Median: There is no raised median, two-way left-turn lane (TWLTL), or median barrier. CARDs are appropriate for flush medians. •Length: The total quantity of CARDs in a project is 1,500 feet (500 m) or more. Because of the cost of mobilizing the equipment to mill in the CARDs, projects that would result in the total placement of less than 1,500 feet (500 m) may be exempted. •Speed: The posted speed is 45 mph or greater. The likelihood of a severe injury or fatality increases dramatically in collisions of 45 mph (70 km/h) or greater. •Volume: A current AADT of 2,000 vpd or more. The primary benefit of CARDs is to reduce the incidence of head-on and opposite direction sideswipe collisions. As traffic volumes decrease, the likelihood of such collisions decreases, with or without the use of CARDs. •Roadway Width: The combined width of the lane(s) and shoulder, in each direction, must be at least 13 ft (3.9 m).						
OH	Yes	Rarely	http://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/traffic/TEM/Pages/default.aspx 1415 RUMBLE STRIPS (INCLUDING STRIPES) IN THE ROADWAY						
OR	Yes	Often	Same as in Table B12						
PA	Yes	Often							
SC	Yes	Sometimes							
SD	Yes	Sometimes	http://www.sddot.com/business/design/docs/rd/rdmch07.pdf						
TX	Yes	Often							

TABLE B13. States' Use of Center Line Rumble Strip

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
UT	Yes	Sometimes	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/243-a5b63c96154e5159de93650862b7110f_UDOT_Ruble_Strip_Std_Dwgs_2017.pdf Standard drawings are attached.						
VA	Yes	Sometimes	See response on Table B11						
VT	Yes	Often	http://vtrans.vermont.gov/sites/aot/files/highway/documents/structures/HSDEI%2014-101%20-%20Guidelines%20For%20Milled%20CLRS.pdf http://vtrans.vermont.gov/highway/safety/rumblestripes						
WA	Yes	Often							
WI	Yes	Often	http://wisconsindot.gov/rdwy/fdm/fd-11-15.pdf						
WV	Yes	Often							

TABLE B14. States' Practices for Use of Raised Thermoplastic Markings

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	No							✓	
AL	Yes	Rarely							
AR	Yes		http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/203-94fcefb93a93ff494a930dbb58890187_Policy_for_the_Use_of_Rumble_Strips_20120403.pdf						
AZ	Yes	Often							
CO	No					✓		✓	
CT	No					✓			
DE	No							✓	
FL	Yes	Often	http://www.fdot.gov/roadway/Bulletin/RDB15-02.pdf						
GA	Yes	Often							
HI	No								Currently being tested to replace bot dots. These do not seem as effective as MRS in alerting drivers.
ID	No			✓					
IL	Yes	Rarely							
IN	Yes	Sometimes							
KS	No							✓	
KY	No							✓	
LA	Yes	Rarely	We are in the process of piloting this countermeasure, but it is too soon for evaluation.						
MA	No							✓	
MD	No			✓					

TABLE B14. States' Practices for Use of Raised Thermoplastic Markings

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
ME	No								Winter maintenance - RPM's are scraped off at the first winter plowing.
MI	No							✓	
MN	No							✓	
MS	Yes	Rarely	I know these have been used, but they are not used extensively. I'm not sure if these have been used in the last few years.						
MT	No							✓	
NC	Yes	Sometimes	The profile markings are very susceptible to snowplows.						
ND	Yes	Sometimes	http://www.dot.nd.gov/manuals/design/designmanual/Chapter%203.pdf						
NE	No							✓	
NH	No					✓		✓	
NV	Yes	Sometimes	thermo plastic is used down south, not so much in the north unless its recessed.						
NY	No								
OH	No				✓				
OR	Yes	Often	Would like to see any research on the effectiveness, anecdotally these have the same benefit as rumble strips						
PA									
SC	Yes	Often							
SD	No							✓	
TX	Yes	Often							

TABLE B14. States' Practices for Use of Raised Thermoplastic Markings

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
UT	No								Winter conditions, snowplow operations.
VA	No					✓		✓	
VT	Yes	Sometimes	However, this is usually used at intersections						
WA	Yes	Often							
WI	No							✓	The big maintenance concern is being removed with snow plows.
WV	No							✓	

TABLE B15. States' Practices for Use of SafetyEdge[SM]

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Rarely							
AL	No								Working to incorporate this procedure into our standard practice. Some resistance from contractors based on liability.
AR	No		http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/99-236ce59110d2a5371b6e6b3af2ed5db2_Policy_for_the_Use_of_Rumble_Strips_20120403.pdf						
AZ	Yes	Often							
CO	Yes	Sometimes	https://www.codot.gov/business/designsupport/standard-plans/2006-m-standards/2006-project-special-details/safety-edge-for-pavement						
CT	No					✓			
DE	Yes	Often	Used on all projects with an exposed pavement edge. http://www.deldot.gov/Publications/manuals/dgm/pdfs/1-25_safety_edge_revised.pdf						
FL	Yes	Rarely	http://www.fdot.gov/programmanagement/OtherFDOTLinks/Developmental/Files/Dev330SE.pdf						
GA	Yes	Often							
HI	Yes	Often	Required on all resurfacing projects						

TABLE B15. States' Practices for Use of SafetyEdge[SM]

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
ID	Yes	Sometimes	ITD standard is to use a 18" to 24" shoe. The safety edge is an option in areas where the shoe is not feasible. http://apps.itd.idaho.gov/apps/manuals/RoadwayDesign/Roadwaydesignprintable.htm						
IL	No					✓	✓		
IN	Yes	Often							
KS	Yes	Sometimes	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/240-541fc57b23b5434fb2ddd4267ed7a5e5_Road_Memo_13-01.pdf http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/74-4673046e9f63c01f165a88b62e323d00_15-08004-R01_-_TAPERED_PAVEMENT_EDGE.doc						
KY	Yes	Sometimes	http://transportation.ky.gov/Construction/Standard%20amd%20Supplemental%20Specifications/Supplemental%20Specifications%20Effective%20with%20February%2024,%202017%20Letting.pdf Revise sections: 403.02.07, 403.03						
LA	Yes	Often							
MA	Yes	Rarely	Using Safety Edge in a few test locations - no guideline or policy						
MD	Yes	Rarely							
ME	Yes	Sometimes							

TABLE B15. States' Practices for Use of SafetyEdge[SM]

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MI	Yes	Often							
MN	Yes	Often	Part of standard roadway construction now. http://www.dot.state.mn.us/stateaid/safety-edge.html						
MS	Yes	Often	http://sp.mdot.ms.gov/RoadwayDesign/Design%20Memos/2011-05-24.pdf						
MT	Yes	Often	our standard details for paving already incorporates a similar design.						
NC	Yes	Often							
ND	Yes	Often							
NE	Yes	Often							
NH	Yes	Often							
NV	Yes	Often	standard practice for all paving projects with a 3 inch or greater PBS lift						
NY	Yes	Often							
OH	Yes	Often	https://www.dot.state.oh.us/Divisions/Engineering/Pavement/Safety%20Edge%20Info/Forms/AllItems.aspx						
OR	Yes	Often	ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/roadway/2017_01/rd610.pdf design details for Safety edge included in every overlay project when shoulders are 6 feet or less						
PA	No								NJDOT has its own design standard
SC	Yes	Often							

TABLE B15. States' Practices for Use of SafetyEdge[SM]

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
SD	Yes	Sometimes							
TX	Yes	Sometimes							
UT	Yes	Sometimes	Standard drawing is attached.						
VA	No							✓	
VT	Yes	Often	http://vtrans.vermont.gov/sites/aot/files/highway/documents/structures/HSDEI%2016-101%20-%20Safety%20Edge%20Implementation.pdf						
WA	Yes	Often							
WI	Yes	Sometimes	http://wisconsindot.gov/rdwy/fdm/fd-11-45.pdf (Section 11-45-2) Used on roadways with the shoulder < 3 ft. wide.						
WV	Yes	Often							

TABLE B16. States' Practices for Widening Shoulders on Curved Sections

State	Use	Frequence	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Rarely							
AL	Yes	Sometimes							
AR	Yes	Sometimes							
AZ	Yes	Often							
CO	No					✓		✓	
CT	No					✓			
DE	No				✓				
FL	Yes	Rarely							
GA	No			✓					
HI	Yes	Rarely							
ID	Yes	Rarely	We have done shoulder widening around curves to mitigate truck off-tracking issues.						
IL	Yes	Sometimes							
IN	No								
KS	Yes	Sometimes							
			http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/133-bc0d554735a4d335255a301d057f408c_HSIP%2BFAST%2BPlanning%2BDRAFT.pdf						

TABLE B16. States' Practices for Widening Shoulders on Curved Sections

State	Use	Frequence	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
KY	Yes	Sometimes	23 U.S.C. 148(h)(4) and 23 U.S.C. 409. All documents are provided for research purposes only and is not to be disseminated within the report itself. DRAFT document for the "basics" of how we administer HSIP. Shoulder widening evaluated as part of FD05 Shoulder and RD Corridor projects.						
LA	Yes	Sometimes							
MA	Yes	Rarely	case by case basis						
MD	No				✓	✓			
ME	Yes	Sometimes							
MI	Yes	Often							
MN	Yes	Sometimes	Mostly thru HSIP Selection and reconstruction on Trunk Highways. Typically it has been done more in the past for erosion control issues then safety issues.						
MS	No								Especially on some of the more rural routes, the ROW footprint is tight and becomes a significant hurdle to implementation of this countermeasure.
MT	Yes	Sometimes							
NC	Yes	Often							
ND	Yes	Sometimes	Plan on doing more in the future through systemic process.						
NE	Yes	Sometimes							
NH	No			✓					

TABLE B16. States' Practices for Widening Shoulders on Curved Sections

State	Use	Frequence	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
NV	No								we have not done this yet but will be looking into spot locations with our upcoming CIP mentioned earlier
NY	Yes	Sometimes							
OH	Yes	Rarely							
OR	Yes	Rarely							
PA	Yes	Sometimes							
SC	Yes	Sometimes							
SD	Yes	Sometimes							
TX	Yes	Sometimes							
UT	Yes	Rarely							
VA	Yes	Rarely	a few HSIP projects that were curve specific. Several that were corridor shoulder widening, with RStrips and GRail.						
VT	Yes	Rarely	Would be done as part of a paving project.						
WA	No					✓			
WI	No								Constructability.
WV	Yes	Sometimes							

TABLE B17 States' Practices for Use of High Friction Surface Treatment

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Rarely							
AL	Yes	Rarely							
AR	Yes	Often							
AZ	No					✓			
CO	No								Still learning about HFST.
CT	Yes	Sometimes							
DE	Yes	Sometimes	No current policy exists. Can provide specifications if needed. Sites are selected systemically.						
FL	Yes	Sometimes	http://www.fdot.gov/programmanagement/OtherFDOTLinks/Developmental/Files/Dev333.pdf						
GA	Yes	Often							
HI	Yes	Rarely	Costly in Hawaii and durability is questionable						
ID	No								Not aware of any implementation of this countermeasure in Idaho. Cost may be an issue.
IL	Yes	Sometimes							
IN	Yes	Rarely	INDOT is executing its first HFST projects this fiscal year, investing roughly $1 million. We plan to continue the program in future years. The treatment is almost exclusively reserved for horizontal curves.						
KS	Yes	Sometimes							
KY	Yes	Sometimes	See HSIP Investment Plan. High Friction Surface projects.						

TABLE B17 States' Practices for Use of High Friction Surface Treatment

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
LA	Yes	Sometimes	See systemic analysis previously provided. We've also spot-treated a few locations based on crash data analysis results.						
MA	Yes	Rarely	Using HFST in a few test locations - no guideline or policy						
MD	Yes	Rarely	There are some applications in place already. MDOT is looking to further the use of this treatment.						
ME	Yes	Rarely							
MI	Yes	Sometimes							
MN	Yes	Rarely	Still somewhat experimental. We are working on greater deployment.						
MS	Yes	Sometimes	http://mdot.ms.gov/bidsystem_data/20150623/PROPOSALS/107003301.pdf (Page 162 of the PDF is the special provision for the construction of this treatment). I'm unaware of any policy.						
MT	Yes	Sometimes							
NC	Yes	Rarely							
ND	No								Plan to implement soon.
NE	Yes	Sometimes							
NH	Yes	Rarely							
NV	Yes	Rarely	we just installed the first location on a curve along with the dynamic chevrons						
NY	Yes	Sometimes							

TABLE B17 States' Practices for Use of High Friction Surface Treatment

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
OH	Yes	Rarely	Both HFST and pavement grooving have been used in areas where a significant proportion of crashes are wet pavement related.						
OR	Yes	Rarely	We are in the process of installing some still some of the hurdles seem to be from pavements group and how often it has to be replaced						
PA	Yes	Sometimes							
SC	Yes	Sometimes							
SD	Yes	Sometimes							
TX	Yes	Sometimes							
UT	Yes	Rarely							
VA	Yes	Sometimes	some Districts have tried and others are about to implement contracts						
VT	Yes	Rarely	We experimented with this in the past:						
			http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/2014%20-%2002%20Ennis%20Paint%2C%20Inc.%20Tyregrip%20High%20Friction%20Surface%20System.pdf						
WA	Yes	Rarely							

TABLE B17 States' Practices for Use of High Friction Surface Treatment

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
WI	Yes	Rarely	WisDOT currently does not have a policy or guidelines regarding when to use HFST. They are primarily funded through the HSIP program.						
WV	Yes	Often							

TABLE B18 States' Practices for Use of Pavement Grooving

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	No							✓	
AL	Yes	Rarely							
AR	No								
AZ	No								Other.
CO	No			✓					
CT	Yes	Rarely							
DE	Yes	Sometimes	No guidance exists. Used on a case-by-case basis.						
FL	Yes	Sometimes							
GA	No			✓					
HI	No								Very rarely used
ID	No			✓					
IL	No			✓				✓	
IN	Yes	Rarely							
KS	Yes	Rarely							
KY	No				✓			✓	
LA	Yes	Sometimes	On bridge decks. Also, shot abrasion is used as an alternative.						
MA	No			✓					
MD	Yes	Rarely							
ME	No							✓	
MI	Yes	Sometimes							
MN	No			✓					
MS	No								Not really sure why it is not used. Some concrete sections are diamond ground to aid with smoothness, but Mississippi has very few concrete sections.

TABLE B18 States' Practices for Use of Pavement Grooving

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MT	No								this was shown as not being very effective on bridge decks; MDT is now favors epoxy skid treatments.
NC	Yes	Rarely							
ND	No			✓					
NE	Yes	Often	Yes, Often, if this question is referring to the tinning of all concrete travel lanes						
NH	No			✓					
NV	No								
NY	Yes	Rarely							
OH	Yes	Sometimes	Both HFST and pavement grooving have been used in areas where a significant proportion of crashes are wet pavement related.						
OR	Yes	Rarely	Not part of a safety program, but part of pavements group repair strategies						
PA									
SC	Yes	Sometimes							
SD	Yes	Often							
TX	Yes	Sometimes							
UT	No			✓					
VA	Yes	Rarely	Pavement management if wet crashes were identified. Not sure how often used in recent years.						
VT	No			✓					
WA	Yes	Rarely							
WI	No response								

TABLE B18 States' Practices for Use of Pavement Grooving

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
WV	No							✓	

TABLE B19 States' Practices for Use of Cable Median Barrier

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	No							✓	
AL	Yes	Often							
AR	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-12659baf51837ed8c61a5c1484c5ee34_Cable_Median_Barrier_Policy.pdf						
AZ	Yes	Often							
CO	Yes	Often							
CT	Yes	Sometimes							
DE	Yes	Sometimes	No guidance exists. Used on freeway medians. In process of utilizing countermeasure to close all freeway medians in the state.						
FL	Yes	Sometimes	http://www.fdot.gov/roadway/Bulletin/RDB15-05.pdf						
GA	Yes	Often							
HI	Yes	Rarely	Very rarely used due to maintenance concerns						
ID	Yes	Rarely							
IL	Yes	Often							
IN	Yes	Often	About half of the state's 1,200 centerline miles of Interstate System has cable median barrier. (Of course, some of the state's Interstates are urban or suburban, with other form of barrier separation, for instance, concrete median barrier, or 2-sided W-beam.)						
KS	Yes	Rarely							
KY	Yes	Sometimes	See HSIP Investment Plan. Cable Barrier projects.						

TABLE B19 States' Practices for Use of Cable Median Barrier

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
LA	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-391e942076f3c051d60a46828547fa8a_Cable_Barrier_Final_Draft_V6.pdf						
MA	Yes	Sometimes	Countermeasure was implemented after statewide analysis/RSA of 20+ locations.						
MD	Yes	Sometimes							
ME	Yes	Often	Medians 50' wide or narrower.						

TABLE B19 States' Practices for Use of Cable Median Barrier

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MI	Yes	Often	The results of the 'Study of High Tension Cable Barrier on Michigan Roadways' research, completed by Wayne State University, show that cable median barriers have been highly effective at reducing crossover crashes in Michigan. After the barriers were installed, crossover crash rates on those freeway segments fell by 87 percent, and the barriers successfully contained 97 percent of the vehicles that hit them. Cable barriers have improved overall safety at the locations where they have been installed. The most serious crashes—fatal and severe injury crashes—decreased by 33 percent after cable median barriers were installed, according to statistical analysis. Since their installation, cable median barriers are estimated to have saved 20 lives and prevented over 100 serious injuries in Michigan. http://www.michigan.gov/mdot/0,1607,7-151-9615_11261_55772---,00.html						
MN	Yes	Sometimes	Implemented on high volume and narrow median stretches. Minnesota currently has about 500 miles implemented.						

TABLE B19 States' Practices for Use of Cable Median Barrier

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MS	Yes	Sometimes	http://mdot.ms.gov/bidsystem_data/20140722/PROPOSALS/106780301.pdf (Page 73 of the PDF shows the typical sections for the installation), Page 220 is the standard specification.						
MT	Yes	Often							
NC	Yes	Often							
ND	No							✓	
NE	Yes	Rarely							
NH	Yes	Often							
NV	Yes	Often	we look at locations where the median is less than 50 feet						
NY	Yes	Sometimes							
OH	Yes	Often	https://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/roadway/Pages/HighTensionCableBarrier.aspx						
OR	Yes	Often	We use this quite a lot in Oregon even used on a four lane section with narrow median						
PA	No							✓	
SC	Yes	Often							
SD	Yes	Rarely							
TX	Yes	Often							
UT	Yes	Often	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/250-3c1d394f24cd91c356746c3732b6d002_Cable_Barrier_Standard_Drawings.pdf Standard drawings are attached.						

TABLE B19 States' Practices for Use of Cable Median Barrier

State	Use	Frequency	URL for relevant file/Comments	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
VA	Yes	Sometimes	used on limited access facilities without existing barriers and with appropriate cross slopes and deflection clear zone.						
VT	No								We looked at crossover crashes on the interstate several years ago. It was determined that it was not a significant issue.
WA	Yes	Often							
WI	Yes	Often	http://wisconsindot.gov/rdwy/fdm/fd-11-45.pdf						
WV	Yes	Sometimes							

TABLE B20 States' Practices for Increasing Clear Zone

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Sometimes							
AL	No					✓	✓	✓	
AR	No								
AZ	No					✓			
CO	No					✓			
CT	Yes	Sometimes							
DE	No					✓			Right-of-way constraints.
FL	Yes	Sometimes	http://www.fdot.gov/roadway/ppmmanual/2017/Volume1/2017Volume1.pdf FDOT Plans Prep Manual, Chapter 4, Roadside Safety						
GA	No				✓				
HI	No								Hawaii has very limited right-of-way and clear roadside
ID									
IL	No						✓		Designers typically do not exceed clear zone minimum requirements.
IN	Yes	Rarely							
KS	Yes	Sometimes							
KY	No					✓	✓	✓	
LA	Yes	Sometimes							
MA	No								
MD	Yes	Sometimes							
ME	Yes	Rarely							
MI	No					✓			

TABLE B20 States' Practices for Increasing Clear Zone

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MN	Yes	Sometimes	Designers are encouraged to remove large hazards beyond the clear zone. This can often be difficult. Road Design Manual covers this: https://roaddesign.dot.state.mn.us/						
MS	Yes	Rarely	This is typically hard to get approval to do, though.						
MT	Yes	Often	Designers strive to get as much clear zone that is available.						
NC	Yes	Rarely							
ND	No			✓					
NE	Yes	Sometimes							
NH	Yes	Rarely							
NV	Yes	Sometimes	this is not used that often but where there is sufficient ROW and crash data to support						
NY	Yes	Sometimes							
OH	No				✓				
OR	Yes	Rarely							
PA									
SC	Yes	Sometimes							
SD	Yes	Rarely							
TX	No			✓					
UT	Yes	Often	Primarily on interstate highways						
VA	No					✓	✓		

TABLE B20 States' Practices for Increasing Clear Zone

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
VT	Yes	Sometimes	The designer may choose to increase the clear zone width on the outside of horizontal curves where accident histories indicate a need, or where specific site investigation shows a definitive accident potential. This may be cost effective where increased banking or other accident countermeasures are not feasible. Search for clear zone in the following document to go to this statement in the Vermont State Standards. http://vtrans.vermont.gov/sites/aot/files/highway/documents/publications/VermontStateDesignStandards.pdf						
WA	No					✓		✓	
WI	No					✓	✓		Not expanding the clear zone requires less ROW. Also, many times the project type, repaving for example, is not scoped for acquiring the necessary ROW to increase the clear zone.
WV	Yes	Sometimes							

TABLE B21. States' Practices for Flattening Side Slopes

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Sometimes							
AL	Yes	Rarely							
AR	No								
AZ	Yes	Rarely							
CO	Yes	Sometimes							
CT	Yes	Rarely							
DE	Yes	Rarely	Used on a case-by-case basis.						
FL	Yes	Sometimes	FDOT Plans Prep Manual (Vol 1), Ch 23, Design Exceptions and Design Variations http://www.fdot.gov/roadway/ppmmanual/2017/Volume1/2017Volume1.pdf						
GA	No				✓				
HI	Yes	Rarely	Hawaii has very limited right-of-way and clear roadside (cut/fill sections)						
ID									
IL	Yes	Sometimes							
IN	Yes	Sometimes							
KS	Yes	Sometimes							
KY	Yes	Sometimes	See HSIP Investment Plan. FD05 Shoulder and RD Corridor projects.						
LA	Yes	Sometimes							
MA	No							✓	
MD	No			✓					
ME	Yes	Sometimes							
MI	Yes	Sometimes							

TABLE B21. States' Practices for Flattening Side Slopes

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MN	Yes	Rarely	Mostly done during reconstruction. Not an active program to complete this. Road Design Manual covers this: https://roaddesign.dot.state.mn.us/						
MS	Yes	Rarely	We hope to use this more in the future to help move the cable barrier from the shoulder to the center of the ditch, to help eliminate nuisance hits.						
MT	Yes	Often							
NC	No								Usually flattening the side slopes is not an economically feasible alternative, particularly in the mountainous areas.
ND	Yes	Sometimes							
NE	Yes	Sometimes							
NH	Yes	Sometimes							
NV	Yes	Often	we are currently have several shoulder widening and slope flattening projects in various stages. in design and in construction						
NY	Yes	Sometimes							
OH	No				✓				
OR	No								Don't believe we have used this but it is available, this fits the remove obstacle or flatten side slope

TABLE B21. States' Practices for Flattening Side Slopes

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
PA									
SC	Yes	Sometimes							
SD	Yes	Sometimes							
TX	No			✓					
UT	Yes	Rarely							
VA	Yes	Rarely	Typically 3R or widening project driven.						
VT	Yes	Sometimes							
WA	Yes	Often							
WI	Yes	Rarely							
WI	No					✓			Also has ROW restrictions and is of the wrong project type. In some cases, the designers don't believe it to be effective.
WV	Yes	Sometimes							

TABLE B22 States' Practices for Removing Trees

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Sometimes							
AL	Yes	Rarely							
AR	Yes	Sometimes							
AZ	Yes	Often							
CO	Yes	Rarely							
CT	Yes	Often							
DE	Yes	Rarely	Case-by-case basis. No policy of guidelines exist to document when to use.						
FL	Yes	Sometimes							
GA	Yes	Rarely							
HI	Yes	Rarely	Outdoor Circle concerns						
ID									
IL	Yes	Sometimes							
IN	Yes	Sometimes							
KS	Yes	Rarely							
KY	Yes	Rarely	See HSIP Investment Plan. FD05 Shoulder and RD Corridor projects.						

TABLE B22 States' Practices for Removing Trees

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
LA	Yes	Sometimes	There have been a few projects that the Districts requested. We need a better way to prioritize, as stated above. Also, we need better guidance on how this relates to speed. If operating speeds are low, perhaps the fixed objects aren't as "dangerous" as compared to when a facility operates at a higher speed. Also, we mow a lot of grass in Louisiana. This would increase our maintenance costs.						
MA	Yes	Rarely	case by case basis						
MD	Yes	Rarely							
ME	Yes	Sometimes							
MI	Yes	Often							
MN	Yes	Sometimes	Part of clear zone maintenance and reconstruction. Road Design Manual covers this:						
			https://roaddesign.dot.state.mn.us/						
MS	Yes	Rarely	Like with #20, this is very hard to get approved, especially in the Coastal Counties.						
MT	Yes	Sometimes							
NC	Yes	Rarely							
ND	Yes	Sometimes							
NE	Yes	Sometimes							
NH	Yes	Sometimes							

TABLE B22 States' Practices for Removing Trees

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
NV	Yes	Rarely	what's a tree? kidding, most of our trees are in mountainous terrain and protected by guardrail. if a tree is in clear zone, it takes an act of congress to get it removed.						
NY	Yes	Sometimes							
OH	Yes	Rarely	As related to intersection sight distance.						
OR	Yes	Sometimes	Somewhat of a hard thing to do in some areas, in other areas there seems to be no problem, very hard in national forests						
PA	Yes								
SC	Yes	Sometimes							
SD	Yes	Sometimes							
TX	Yes	Sometimes							
UT	No								Not a significant issues in our predominant desert climate
VA	Yes	Rarely	on own, not 3R or construction project driven, only limited clearing within ROW on limited access facilities and a few non-controlled primaries with tree crash problem ID.						
VT	Yes	Rarely	This is something that would be done at hot spot locations						
WA	Yes	Often							
WI	Yes	Sometimes	WisDOT does not have any written policy or guidance.						
WV	Yes	Rarely							

TABLE B23 States' Practices for Increasing Sight Distance

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Sometimes							
AL	Yes	Rarely							
AR	Yes	Sometimes							
AZ	No					✓			
CO	Yes	Sometimes							
CT	Yes	Rarely							
DE	Yes	Rarely	Used on a case-by-case basis. Requires additional right-of-way in some cases.						
FL	Yes	Sometimes	FDOT Plans Prep Manual (Vol 1), Ch 23, Design Exceptions and Design Variations http://www.fdot.gov/roadway/ppmmanual/2017/Volume1/2017Volume1.pdf						
GA	Yes	Rarely							
HI	Yes	Rarely	Hawaii has very limited right-of-way and clear roadside						
ID									
IL	Yes	Sometimes							
IN	Yes	Sometimes							
KS	Yes	Sometimes	Typically as part of a reconstruct.						
KY	Yes	Sometimes	See HSIP Investment Plan. RD Corridor projects.						
LA	Yes	Sometimes							
MA	Yes	Sometimes	case by case basis						
MD	Yes	Rarely							
ME	Yes	Rarely							

TABLE B23 States' Practices for Increasing Sight Distance

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
MI	Yes	Often							
MN	Yes	Rarely	Mostly done on reconstruction on sites that don't meet standards or have crash issues. No active program to address this issue. Mostly covered by road design manual: https://roaddesign.dot.state.mn.us/						
MS	Yes	Rarely	We've tried to do these at a few vertical curves on 4-lane divided routes, but it's hard to get approved to close one side of the road down to modify these type curves.						
MT	Yes	Sometimes							
NC	Yes	Sometimes							
ND	Yes	Sometimes							
NE	Yes	Sometimes							
NH	Yes	Sometimes							
NV	No								
NY	Yes	Sometimes							
OH	Yes	Rarely							
OR	Yes	Sometimes	Maintenance keeps this up within the right of way section						
PA	Yes								
SC	Yes	Sometimes							
SD	Yes	Sometimes							
TX	Yes	Rarely							
UT	Yes	Rarely							
VA	No					✓			

TABLE B23 States' Practices for Increasing Sight Distance

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
VT	Yes	Sometimes							
WA	Yes	Sometimes							
WI	Yes	Rarely	This is not done very often and as such there is no written policy. When a project would like to increase the sight distance on curves an exception is needed.						
WV	Yes	Rarely							

TABLE B24 States' Practices for Improving Superelevation

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
AK	Yes	Sometimes							
AL	Yes	Often							
AR	Yes	Sometimes							
AZ	Yes	Rarely							
CO	Yes	Sometimes							
CT	Yes	Rarely							
DE	Yes	Sometimes	Typically done through pavement wedging. No specific guidelines or policy exists.						
FL	Yes	Sometimes	FDOT Plans Prep Manual (Vol 1), Ch 23, Design Exceptions and Design Variations http://www.fdot.gov/roadway/ppmmanual/2017/Volume1/2017Volume1.pdf						
GA	No				✓				
HI	Yes	Rarely	Hawaii has very limited right-of-way and clear roadside (cut/fill sections)						
ID									
IL	Yes	Rarely							
IN	Yes	Rarely							
KS	Yes	Sometimes	Typically as part of a reconstruct or resurfacing.						
KY	Yes	Sometimes	See HSIP Investment Plan. High Friction Surface and RD Corridor projects.						

TABLE B24 States' Practices for Improving Superelevation

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
LA	Yes	Sometimes							
MA	Yes	Rarely	case by case basis						
MD	Yes	Rarely							
ME	Yes	Rarely							
MI	Yes	Often							
MN	Yes	Rarely	Mostly done on reconstruction on sites that don't meet standards or have crash issues. No active program to address this issue. Mostly covered by road design manual: https://roaddesign.dot.state.mn.us/						
MS	Yes	Rarely	This is a spot treatment that we've tried a few times.						
MT	Yes	Rarely							
NC	Yes	Sometimes							
ND	Yes	Sometimes							
NE	Yes	Sometimes							
NH	Yes	Often							
NV	No								
NY	Yes								
OH	No				✓				
OR	Yes	Rarely	Pavements may do this not part of our normal safety countermeasures						
PA	Yes								
SC	Yes	Sometimes							

TABLE B24 States' Practices for Improving Superelevation

State	Use	Frequency	URL for relevant file or Comment	If not, why					
				Not aware of C/M	C/M not proven cost effective	Insufficient funding	Negative Public Feedback	Maintenance Concerns	Other Reason
SD	Yes	Sometimes							
TX	Yes	Rarely							
UT	Yes	Rarely							
VA	Yes	Rarely	A few maintenance/overlay improvements and a few HSIP projects						
VT	Yes	Often	Horizontal curves are reviewed as part of paving projects and corrected as applicable						
WA	Yes	Sometimes							
WI	Yes	Rarely	http://wisconsindot.gov/rdwy/fdm/fd-11-40.pdf						
WV	Yes	Sometimes							

TABLE B25. Other Countermeasures Being Used By States

State	Other Countermeasures Not Mentioned Previously
AK	Passing lanes. More for lane departure, but does impact roadway departure crashes. Roads connecting our urban centers are rural two lane roads with high seasonal volume variances, so the passing lanes help with aggressive driving.
AL	In the process of resigning all horizontal curves on the state maintained system. Final signing will bring all curve signing up to the MUTCD 2009 edition guidance. As part of the project, we will be using fluorescent yellow sheeting for all horizontal curve series signs.
AR	We have used concrete pavement surface abrasion for roadway departure crashes and have seen a noticeable improvement in reducing wet pavement, roadway departure crashes. As well, Ultra-thin Bonded Wearing Course has been a good countermeasure for wet pavement crashes. Some of our district forces have used mine chat as a surface friction treatment for curves with good results.
CO	Embedded LED's in pavement
FL	Florida Wrong Way Driving Study
	http://www.fdot.gov/traffic/PDF/Wrong%20Way%20Crash%20Study%20-%20Final%20Report-8-15.pdf
GA	1.Retro-reflective warning signs and pavement markings
HI	Guardrails, flexible delineators, concrete median barriers, larger warning signs, reflector markers, culvert extensions, speed advisory signs
IN	What we label as "shoulder corrugation," on the shoulder proper, separate from rumble stripE (pavement marking on rumble). All freeways are treated with shoulder corrugation, and other important rural highways, be they multilane or 2 lanes. Enhanced signing & pavement markings (higher visibility, oversized), for instance, on horizontal curves, approaching intersections.
KY	See HSIP Investment Plan. Guardrail projects are performed under FE06 Matching Fund (new guardrail installation) and NHS G/R ETs projects (upgrade existing guardrail end treatments).
MA	Roadway delineators
MN	We have been using HSIP dollars to provide shoulder paving, around 2' in width, that includes rumble strips and safety edge as a part of the project. This has been recommended in District and County Safety Plans.
MS	We are utilizing Audible Thermoplastic Traffic Markings (pucks) on the edge lines of routes that are insufficient for installation of a edge line rumble strip. The special provision for this can be found on Page 133,
	http://mdot.ms.gov/bidsystem_data/20160823/PROPOSALS/305878301.pdf
NH	Systematic curve warning sign projects to be compliant with MUTCD Table 2C-5.
NY	Retro-reflective lane markings on sections of the Thruway and other interstates.
OH	LED in pavement lighting at two locations: Interchange ramp and rural curve.
OR	Widen pavement shoulder throughout Here is a link to the page that has our list of approved CRFs and where we got them from, see the category for Roadway Departure about midway down.
	http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/Pages/ARTS.aspx
PA	HFST
	Roadway delineation See

TABLE B25. Other Countermeasures Being Used By States

State	Other Countermeasures Not Mentioned Previously
SD	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-00602a4ec99af7951a2ab2101e408389_DOT-OS-OT-7.2.docx
UT	Motorcycle Barrier Attenuator (MBA) attaches to standard roadside guardrail to protect errant motorcyclists from impacting the guardrail post during a crash.
VA	MUTCD chevron compliance HSIP projects ongoing. VTTI study also testing curve speed feedback signing
VT	We often use 6" x 8" white delineators on curves when large arrows and chevrons are not "warranted" as per the MUTCD. See page 5 of this document:
	http://vtrans.vermont.gov/sites/aot/files/highway/documents/structures/TEI%2016-200%202009%20MUTCD%20Clarifications.pdf
WI	Raised pavement markers in work zones: see attached file More policy for roadside barriers : (Section 11-45-2)
	http://wisconsindot.gov/rdwy/fdm/fd-11-45.pdf

TABLE B26. Research To Evaluate Safety Effectiveness by States

STATE	Response comment and URL link provided
AL	We have been constructing a 2-ft paved shoulder as roadways are resurfaced. This is most common on state maintained two-lane routes, but also implemented on other routes. Alabama specific research has shown a 25-35% reduction, on average, in roadway departure crashes, with some locations showing a much higher reduction.
CO	https://www.codot.gov/library/traffic/hsip/studies
FL	http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_SF/FDOT-BDK78-977-14-rpt.pdf
KS	Research on CLRS. Good before and after study. Call with questions.
KY	HSIP Report.
LA	See cable median barrier study attached previously.
MA	Cable barrier evaluation
ME	See Rumble Strip performance report provided on earlier question. We will be doing a median cable barrier study in the next 12 months
MI	Cable Median Barriers-- see below
	https://www.michigan.gov/documents/mdot/RC1612_474931_7.pdf
	Rumble Strips -- see below
	http://www.michigan.gov/mdot/0,4616,7-151-9615_11261-191394--,00.html
MN	http://www.dot.state.mn.us/trafficeng/safety/docs/sixinchedgelines.pdf
	http://www.dot.state.mn.us/trafficeng/reports/Effects%20of%20Center-Line%20Rumble%20Strips%20200807.pdf
MS	This study quantitatively documents the safety impact of rumble stripes in Mississippi. Both descriptive and inferential statistics were used to determine the safety impact. Thirteen road segments were selected to collect and process the data for this research project. The results presented in the paper intend to serve as a sample of the impact of this type of programs.
	http://mdot.ms.gov/documents/research/Reports/Interim%20and%20Final%20Reports/State%20Study%20196%20%97%20Effectiveness%20of%20Rumble%20Stripes%20on%20Roadway%20Safety%20in%20Mississippi.pdf
NC	We are currently analyzing wider edge lines in our state. We have a project where we are looking at crash data, speed data, and retro data and comparing 2 lane roads that were restriped with 4 inch lines with standard beads, 4 inch lines with highly reflective beads, 6 inch lines with standard beads, and 6 inch lines with highly reflective beads. We have completed simple before and after data for both speed and crash data on a few optical speed bar locations and are currently doing the same on a few dynamic curve sign locations. For most of the other countermeasures on the list, we have completed a simple before and after evaluation for site specific locations. In these evaluations, we are trying to determine if the pattern of crashes we were trying to treat changed from the before to the after period. Within each of these evaluations, we provide before and after crash data and collision diagrams. We do this for all of our Safety Projects. we have approximately 1300 evaluations on the web by countermeasure. The web link is below:
	https://connect.ncdot.gov/resources/safety/Pages/Safety-Evaluation.aspx

TABLE B26. Research To Evaluate Safety Effectiveness by States

STATE	Response comment and URL link provided
NV	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/21-7170550147607ad30ebe73c3ea715b25_Case%2BStudy%2BNV%2Broadside%2Bslope%2Bimprovement.docx
OR	We have done checks of rumble strips more informally we intend to document in future, we have seen better than average CRFs in Oregon. Generally we use the CRF clearinghouse or other research for all of our CRFs
SD	HFST applied on horizontal curves with overrepresentation of road departure crashes during winter road condition crashes.
	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/31-a6937b6f0f0eef3982f0ad5315e18017_SDDOT%2B-%2BAID%2BDemo%2BFinal%2BReport.pdf
TX	http://surveygizmoresponseuploads.s3.amazonaws.com/fileuploads/64484/3221238/99-b77534f8d0320c70c77d1429835ad16e_HSIP_Work_Codes_Final.docx
VT	safety effectiveness of centerline rumble stripes.
	http://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/2015%20-%2007%20Evaluation%20of%20the%20Effectiveness%20of%20Centerline%20Rumble%20Stripes%20on%20Rural%20Roads_0.pdf
WI	Cable barrier research: see attached file Flattening slopes: Low maintenance crash cushion: Cost-effective safety treatments for low volume roads: Guardrail length of need:
	http://mwrsf.unl.edu/reportresult.php?reportId=296&search-textbox=slopes
	http://mwrsf.unl.edu/reportresult.php?reportId=267&search-textbox=cushion
	http://mwrsf.unl.edu/reportresult.php?reportId=8&search-textbox=trees>>
	http://mwrsf.unl.edu/reportresult.php?reportId=297&search-textbox=length of need

TABLE B27. States' Need for More Evaluation of Countermeasures

State	More evaluation/research needed
AL	Centerline rumble strips are being delayed in part due to concerns over pavement maintenance. My research has found that this is not an issue, but there persists a concern amongst the pavement engineers that the scoring will be detrimental and cause the pavement to fail prematurely.
AR	Rumble strips and shoulder widening
AZ	CMF for Tree Removal -- AZDOT completed a research on data needs (SPR-721). Available online (www.azdot.gov/research).
CO	Embedded LED's
IN	Rumble stripE, notably manner of pavement marking on the rumble, and how or whether to use in combination with RPMs.
KS	Cable median barrier in otherwise recoverable medians. Shoulder rumble strips on narrow shoulders.
KY	Signs. We do corridor upgrades of horizontal alignment signing and need to further evaluate the effectiveness of this activity.
LA	tree/fixed object removal related to speed
ME	Went Off Road Crash factors and most effective mitigations (in process)
MN	Sinusoidal Rumble Strips effectiveness. Cost effectiveness of slope flattening, clear zone widening, and tree removals.
MS	I would like to see a study conducted on the efficacy of Audible Thermoplastic Traffic Markings, especially in areas where there is snow and ice that could impact those markings.
MT	sinusoidal rumble strips - how effective are they.....getting negative feedback from folks.
NC	Safety Edge, dynamic curve signs, and wider edge lines (currently working on in house).
NH	Curve warning signing vs. posted speed limits (especially when posted speed limits are significantly less than prevailing speed.
OH	HFST In lane pavement markings
OR	Delineators or similar types of things that can go on narrow shoulders. County roads with deep ditches and narrow shoulders can't put in many of the measures. We need something that is going to not impact their maintenance and that can stay in even delineators though cheap they tend to "mow" them off or knock them off with snow plows, they don't like anything they have to replace every year
SC	Fluorescent sheeting
SD	Roadway delineation.
TX	High Friction Surface Treatments
VA	We are not using but would like to test roadside delineators (flexible tubes) to compare CMF for tangents and curves (with chevrons). would like to see life cycle cost comparisons. ILDOT did some durability studies on freeway installations that I need to follow up on findings.
VT	The use of large (6" x 8") delineators, especially on local rural roads (with low volumes). The use of higher intensity sheeting on curve signs and chevrons/large arrows.
WA	All of them.
WI	Delineating hazards that can't be shielded or moved.

TABLE B28. States That Have Conducted Non-safety Evaluations of Countermeasures

State	Comment and Link to Report
FL	FDOT is in the process of conducting in service performance evaluation for guard rail end treatments for the state maintained system.
GA	We recently conducted some research to determine how well pavement joint located at the center of the roadways have been holding up to center-line rumble strips. Base on that research, we are currently pursuing the approval of a detail calling for two offset rumble to be placed on each side of the roadway center-line to avoid deterioration of pavement along the center-line of the roadway.
IN	At least for freeway median cable barrier, which INDOT has been installing since 2006. I believe ongoing research by JTRP on rumble stripE treatment addresses those "non-safety impacts."
KY	University of Kentucky - Kentucky Transportation Center has performed analysis on markings, RRPMs, and rumble strips.
	http://uknowledge.uky.edu/ktc_researchreports/13/
	http://uknowledge.uky.edu/ktc_researchreports/304/
	http://uknowledge.uky.edu/ktc_researchreports/98/
MI	The research of our Cable Median Barriers included a life cycle cost evaluation.
	https://www.michigan.gov/documents/mdot/RC1612_474931_7.pdf
NC	(No comment provided)
TX	Currently evaluating High Friction Surface Treatments
VA	VTTI study of pavement marking types in and outside of rumble grooves. We are monitoring the initial HFST durability and friction given the pavement in the curve sections chosen were not in good condition.
VT	Tested Safelane overlay and Brifen barrier:
	http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/2013%20-%2006%20An%20Evaluation%20of%20Brifen%20Wire%20Rope%20Safety%20Fence.pdf
	http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/2014%20-%2004%20Cargill%20SafeLane%C2%AE%20HDX%20Overlay.pdf
WA	WSDOT is evaluating the life-cycle of our High Friction Surface Treatment sites.
WI	Additional analysis was conducted for cable barrier.

B29. States Experimenting with New Technology To Reduce Roadway Depart Crashes

State	Technology	Links and/or Comment
FL	Wrong-way Driving Study	http://www.fdot.gov/traffic/PDF/Wrong%20Way%20Crash%20Study%20-%20Final%20Report-8-15.pdf
MN	Sinusoidal Rumble Strips	http://www.dot.state.mn.us/research/TS/2016/201623TS.pdf
		http://www.dot.state.mn.us/trafficeng/safety/docs/sinusoidalrumblestripdesignoptimizationstudy.pdf
	Rumble Strip Noise Evaluation	http://www.dot.state.mn.us/research/TS/2015/201507.pdf
MT	Sequential Dynamic Curve Warning System	http://www.mdt.mt.gov/research/projects/tapco.shtml
ND	Intersection Conflict Warning Systems (ICWS); North Dakota followed Minnesota DOT.	http://www.dot.state.mn.us/trafficeng/signals/conflictwarning.html
OH	LED in pavement lighting at two locations: Interchange ramp and rural curve. These have recently been installed.	
OR		Don't have any research but we have been funding enforcement, but under FAST act can't use HSIP funds any longer, have to use state funds if we still want to do it
SD	Applying HTST on horizontal curves with overreprsentation of road departure crashes during winter road conditions.	See response for Table B26
TX	LED Chevrons with Lead-in Chevron	
WI	New Markings	WisDOT will be testing new markings with National Traffic Products Evaluation Program (along with MN). No information/data at this time, but there will also be a life-cycle cost analysis.

TABLE B30. Actions Being Taken By States for Use of V2V and V2I Technologies

State	Actions Pursing for Use of V2V And V2I Technologies
CO	CDOT has created a Transportation, Systems, Management and Operations Division to incorporate new technology and develop programs. Ryan Rice is Division Director.
CT	CT is in the very preliminary stages of figuring out how to engineer and legislate for Autonomous vehicles. At this point we have not considered the technology to prevent roadway departure crashes.
FL	FDOT has established a Florida Automated Vehicles (FAV) program. Information can be found at URL below; Follow up point of contact is as follows: Florida Dept. of Transportation Systems Planning Office Ed Hutchinson, Manager 605 Suwannee Street Tallahassee, Florida 32399 Phone: (850) 414-4900 Fax: (850) 414-4876 Email: ed.hutchinson@dot.state.fl.us
	http://www.automatedfl.com/
IN	INDOT has asked our research partners (Purdue University, in association with the JTRP program) to advise the agency.
KS	This was a topic at our recent Transportation Safety Conference. But other than such discussion, we have not done much.
KY	Multidisciplinary team meeting to discuss and determine actions needed for future implementation. Contact: David Durman (david.durman@ky.gov)
LA	LADOTD has formed an Autonomous Vehicle Technology Team, which is investigating issues that affect this technology. Steve Glascock is the chair. 225-379-2516
MD	Maryland is just getting involved with the AV &CV. So far much of the focus has been on the policy and regulation side. We are just now starting to work with testing facilities and manufacturers. Nicole Katsikides@sha.state.md.us.
ME	Just keeping up with latest autonomous vehicle technologies and also looking to use vehicle data to identify traffic delays.
MI	Matthew Smith - 517-636-5009 - Intelligent Transportation Systems Manager - SmithM81@michigan.gov
MN	We have researched Work Zone Intrusions (being researched), Rural Curve Warning detection and dynamic signing, miles based user fee research (http://www.dot.state.mn.us/mileagebaseduserfee/.)
NC	We have been involved with initial discussions, meetings, and research that are taking place concerning autonomous vehicles. The contact should be Mr. Kevin Lacy, PE, State Traffic Engineer.
ND	V2V and V2I is being discussed by our Maintenance Division. Contact Brad Darr 701 328-4443
NV	we are watching this evolution closely and watching for those infrastructure improvements that may be required, such as wider edge lines or lidar sensing units along the roadway.
WV	WV has established a TAC to discuss needs to accommodate autonomous vehicles through our research section.

TABLE B31. Actions Being Taken for Autonomous Vehicles

State	Special actions being taken to ensure that the lane boundaries are well defined
AR	Our aim is to restripe the state highway system on a 2-year interval .
CO	Boost funding to striping operation to maintain visible pavement markings
CT	We are trying to make sure edge lines/shoulder lines and centerlines are painted on all state routes. We still have some work to do with municipalities to provide the lane markings for all public roads.
FL	FDOT has established a Florida Automated Vehicles program; information can be found at http://www.automatedfl.com/ (see B30)
HI	Not aware of anything specifically to address AVs; however, District maintenance programs are in place to maintain signs and pavement markings on State roads. In addition, the majority of Hawaii State roads include RPMs on the edge of pavement line. Snow plowing is almost non-existent in Hawaii.
IN	Future of automated and autonomous vehicles has not to this point changed the manner in which we establish and maintain those traffic control devices.
KS	Simply applying our pavement marking policy and doing our best to maintain the longitudinal markings. But we were doing this before autonomous vehicles.
KY	Re-establishing a pavement marking committee.
MD	We have implemented a Pavement Marking Policy with the goal of having performance measures for the condition of our line striping and pavement markers.
MN	State maintains striping on all relevant trunk highways. No additional effort is being considered at this time. Magnetic Tape/ 3M tape has been discussed for winter travel.
NC	In North Carolina, all roads with 100 ADT or greater are stripped with center line and edge lines. Essentially, all roads are stripped.
NH	Annual pavement marking maintenance program; however, we have considered eliminating pavement markings on roads where traffic thresholds do not meet MUTCD Standards (typically 6,000 vpd), which would include a large percentage of state roads. This is due to funding limits.
OR	I would say that a lot of low volume county roads do not have edge lines, we have encouraged local agencies to apply for safety funds to put in edge lines, but because of added costs associated with then maintaining those edge lines I fear some agencies won't put them in.
VA	Ask above contacts but our pavement marking conditions are fairly decent. We do have many miles of rural secondary's < 20 ft that have only CL or no markings.
WI	Using more durable pavement markings to last longer and be more visible (both day and night). Reducing water-born markings and moving to epoxy markings

TABLE 32. Case Examples of Countermeasure Effective in Preventing or Reducing Severity of Crashes

State	Case Examples Provided
AL	We are undertaking a major roadway departure evaluation of our state maintained system with a large number of sites being identified through a network screening of the entire system. We are conducting roadway safety assessments (audits) at all of these locations and including a full range of improvements. The improvements include enhanced signing, high friction surface treatments, superelevation/cross slope corrections, shoulder improvements, clear zone improvements (tree removal, slope improvements, guardrail improvements), access management, rumble strips, etc. As part of the larger roadway departure program, we will be resigning all curves along the state maintained system, to include, removal of existing signing and installation of new signing per the MUTCD, 2009 edition.
AZ	We have not completed any evaluation yet, but shoulder widening with rumble strips seems to be an effective one.
CT	CT is in the project stage for implementing countermeasures to reduce roadway departure. We have had shoulder rumble strips on our limited access roadways for a number of years, but we have only very recently begun installing centerline rumble strips on state routes and local roads. At this time, we have not studied/evaluated implementation of the centerline rumble strips. Additionally, we have a number of projects in either construction or design to install curve warning signs on state routes and local roads throughout the state.
GA	Our state is systematically evaluating all our state routes electronic ballbank indicators in order to identify sharp curves. Once the sharp curve treatments are identified, we develop sharp curve treatment projects which include the implementation of various roadway departure countermeasures such as highly reflective warning signs and pavement markings, edge-line and center-line rumble strips, high friction surface treatment etc.
IN	Internally, the agency recently completed two simple before-after in-service performance studies of our now 10-year-old Interstate median cable barrier program and 4-year-old rumble stripE program. Both concluded that the two treatments were highly effective at reducing risk of severe crashes, particularly fatal events. We expected high effectiveness (CRF) with cable barrier relative to reducing risk of fatal crashes on freeways, but were stunned by apparent positive effectiveness of rumble stripE projects. Overall, INDOT has installed some 1,300 "run-miles" of edgeline and centerline rumble stripE, since 2011. In terms of highly relevant crashes to that countermeasure, of the 54 projects with sufficient "after installation" time to make a reasonable before-after assessment, only one site experienced higher frequency of fatal crashes after vs. before. One outstanding example of sheer before-after effect was on a 17-mile stretch of high-volume, high-speed 2-lane highway -- one of the early projects, with combination of centerline and edgeline rumble stripE -- where 11 fatal crashes took place in the four and a half years just prior to installation but none in the three years since.
KY	https://www.fhwa.dot.gov/innovation/everydaycounts/edc-2/pdfs/edc_hfst_ky.pdf
ME	Centerline Rumble Strips - see response on Table B12

TABLE 32. Case Examples of Countermeasure Effective in Preventing or Reducing Severity of Crashes

State	Case Examples Provided
MI	MDOT has implemented our rumble strip and cable guardrail programs on a system-wide approach. We have also begun including roadway delineation with our trunkline signing contracts. We have begun transitioning the roadway delineation buttons to 3" x 12" panels using sign sheeting. We have begun requiring reflective sheeting on sign posts for all new and upgraded chevrons, double arrows, and stop ahead signs.
MN	We are doing some large scale studies of strategies that were deployed systemically. Nothing is ready at this time, but it may be ready in a year or so.
MS	Mississippi had a number of very serious and/or fatal cross-median crashes in 2007 on a stretch of high speed urban interstate in the Jackson area. One example is this story - http://www.wdam.com/story/7130388/arkansas-man-faces-murder-charge-in-fatal-i-220-wreck. This necessitated our first installation of high tension cable barrier along this interstate highway. Even before the system was fully constructed in 2008, the system was saving lives (see link below). From the initial success stories, MDOT has been able to systemically install cable barrier on all high speed, controlled access, divided highways where the site conditions allowed the installation of this treatment. The initiative to install cable barrier through Mississippi won MDOT an award in 2012 (see link below). While no countermeasure is completely crash proof, it is the belief of MDOT that this treatment has significantly reduced crashes on high speed, controlled access, divided highways across the state.
	http://www.msnewsnow.com/Global/story.asp?S=8906165&nav=2CSf
	https://safety.fhwa.dot.gov/roadwaysafetyawards/2011/npg_2011/#ms
NC	We evaluate all of our Safety Projects with a simple before and after methodology. These projects are site specific and contain before and after crash data as well as before and after collision diagrams. These evaluations are completed to determine if the crash pattern we were trying to treat actually reduced in the after period. All these projects (approximately 1300) are placed on the web at the link below: Contact Shawn A. Troy at stroy@ncdot.gov for additional information.
	https://connect.ncdot.gov/resources/safety/Pages/Safety-Evaluation.aspx
ND	Rumble Strips/Rumble Stripes
NV	see attached document from
OH	We have conducted naive before after evaluation of median cable barrier and edgeline rumble stripes.
VA	we have not completed robust evaluations of our countermeasures, primarily because of the cost keeping the number of sites minimal, nevertheless tracking the locations is lacking, and that multiple countermeasures were often deployed.

TABLE 32. Case Examples of Countermeasure Effective in Preventing or Reducing Severity of Crashes

State	Case Examples Provided
VT	Curve on VT 9 in Woodford, High Friction Surface installation. I believe that signage was also improved. This was a Tyregrip installation. I provided a link to the report in a previous question. The crash data in the table in the appendix represents traffic accidents on US Route 9 approximately between MM 2.8 and MM 3.029. This crash data is between the years of 2006 and 2011. The data represents the number of crashes and fatalities in the three years prior to installation, as well as two years following. In 2009 as well as 2011, no crashes were reported throughout this area. In the three years prior to installation, there were thirteen vehicle crashes, and in the three years following the installation there was only one crash.

TABLE B33. Other Issues Not Previously Raised by States

State	Other issues
AL	An overall push to implement as many of the systemic measures as possible as part of maintenance or new construction is likely the most effective long term solution to bringing down the total number and severity of crashes.
AZ	Driver inattention, fatigue, DUI, etc. are major contributing factors.
CT	Roadway Departure has been identified in our Strategic Highway Safety Plan (SHSP) as part of an emphasis area. We plan to have our SHSP updated by August 2017 so we have been actively reviewing and gathering information about CT's roadway departure crashes. We have not developed a specific implementation plan and since we have only begun to develop/deliver projects, we have not had enough time to evaluate the effects of our projects.
HI	Would like to see more information regarding the feasibility, application, effectivenes, and durability of HFST. Also interested in finding out the effectiveness of buffer medians.
ID	Has there been any studies looking at the impact of rumbles to bicyclists? what about noise concerns, even in rural settings, we have many instances where private homes front the highway.
IN	Crash data precision challenges our ability to efficiently identify/classify crashes of this class; however, the data continually improves over time. Related to that, another challenge is securing reliable information on contributing distractions (distracted driving behavior) pre-event through crash data.
LA	Again, this issue needs to be addressed in context to speed. It also needs to focus on severe crash types. We may not prevent all roadway departure crashes, but if we can save lives and minimize injuries we'd be doing the public a great service.
MI	Due to maintenance and installation costs, some of the countermeasures are not used within Michigan.
MN	Standard Rumbles Strips - Noise. Removing Trees - Can be politically unfeasible Driveways and Embankments are a huge issue - yet very costly to fix on a systematic basis.
OR	Just the one about county roads not having sufficient shoulders and not having any desire to incur maintenance costs, we need a measure that would be cheap and stay in when they mow or snowplow.
VA	Concerns over RPM CFM in HSM/Clearinghouse. VDOT continues to deploy snow plowable RPMs despite the volume thresholds for the CMF. I would like to see this research re-evaluated with a tradeoff of safety and life cycle costs on SP RPMs versus grooved/milled in high build thermo or paint that northern snow states are gravitating towards. perhaps a call for the CMF development PFS.
VT	In Vermont, due to our small number of crashes on local roads and low volumes, it is difficult sometimes to convince towns that chevrons and curve signs should be installed. We are working on a new systemic approach that we hope will help us identify high-risk areas and provide justifications.

TABLE B33. Other Issues Not Previously Raised by States

State	Other issues
WI	1.) The effects of delineation of reducing roadway departure crashes: 2.) Looking into the clear zones for 75 & 80 mph roadways; 3.) Many facets of continuing superelevated shoulder adjacent to the roadway or having a sloped rollover: a. Sensitivity of various slope rollovers (2, 4, 6, 8%); b. Effects of slope rollover location with respect to total shoulder width and paved shoulder width; c. Effects of slope rollover with respect to interaction with roadside crash barrier; and d. Effects of slope rollover with respect to roadway slopes outside of shoulder

APPENDIX C

MASSACHUSETTS LANE DEPARTURE CRASH DATA ANALYSIS, 2002-2004

MASSACHUSETTS LANE DEPARTURE CRASH DATA ANALYSIS, 2002-2004

The development of Strategic Highway Safety Plans (SHSPs) in each state has become a key focus for highway safety professionals nationwide. The Safe, Accountable, Flexible and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) requires each state department of transportation to develop a SHSP. SHSPs serve several purposes: developing common statewide highway safety goals; strengthening existing partnerships and developing new ones; sharing data, knowledge and resources; avoiding redundant activities; communicating the impact of investing additional resources for highway safety countermeasures; and incorporating both behavioral and infrastructure strategies and countermeasures.

Lane departure crashes account for a high percentage of incapacitating injury and fatal crashes in Massachusetts; therefore lane departure crashes are a critical area for consideration as part of the Massachusetts SHSP. In addition, the high percentage of lane departure crashes has led Massachusetts to be designated a lead state in the implementation of the American Association of State Highway and Transportation Officials (AASHTO) Strategic Highway Safety Plan which aims to work towards reducing the US traffic fatality rate to 1.0 fatalities/hundred million vehicle miles traveled (VMT).

Lane Departure Crashes are...

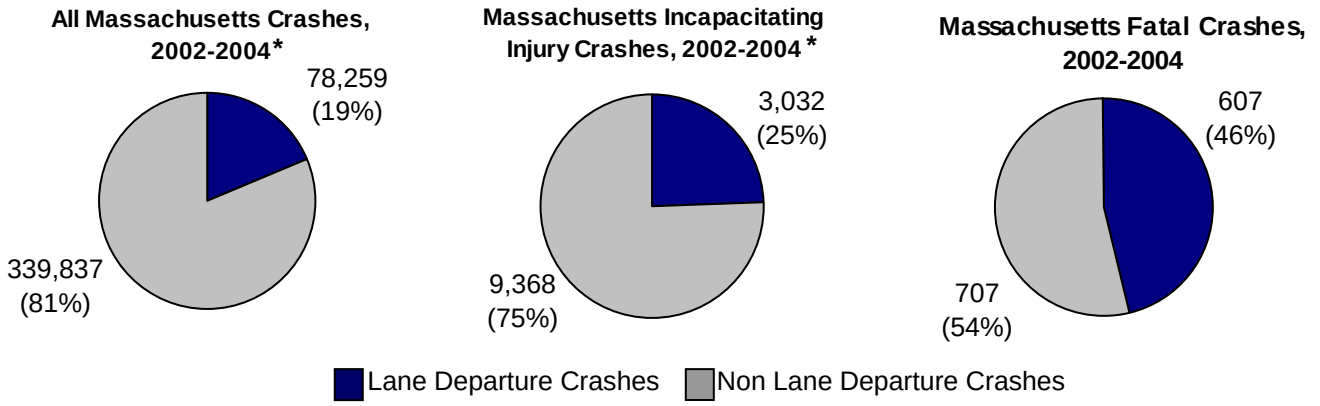
non-intersection crashes where the vehicle

- leaves the roadway but does not strike another moving vehicle, or
- collides with a parked vehicle, or
- collides head on with another vehicle.

Photo Source: FHWA

Massachusetts Lane Departure Crashes, 2002-2004

Lane departure crashes account for a larger percent of crashes as injury severity increases. While lane departure crashes account for 19% of all crashes, they account for **nearly 1/2 of all fatal crashes**.



- Lane departure crashes were **four times more likely to be fatal** than non lane departure crashes.
- While Interstate roads account for 27% of vehicle miles traveled in MA, **only 10% of fatal and incapacitating injury lane departure crashes occurred on Interstate roads**.
- In recent years (2003-2004), **speeding was a factor in 44% of fatal lane departure crashes** compared to only 32% of all fatal crashes.
- Incapacitating injury lane departure crashes were **two times more likely to occur on icy/snowy/slushy roads** than all incapacitating injury crashes.

Prepared by umass Safe Traffic Safety Research Program

*2004 non-fatal crash data based on crash reports submitted to Registry of Motor Vehicles prior to 7/16/2005.

COLLISION CHARACTERISTICS

Most Severe Crashes (Fatal & Incapacitating Injury Crashes)

Massachusetts Lane Departure Fatal + Incapacitating Injury Crashes, 2002-2004*

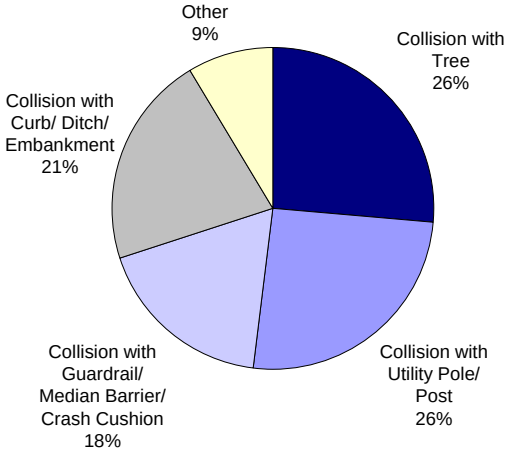
Year	Fatal + Incapacitating Injury Crashes			All Fatal + Incapacitating Injury Crashes
	Run Off Road Single Vehicle/ Collision with Parked Car	Head On	Lane Departure Total	
2002	1,035	188	1,223	4,612
2003	934	215	1,149	4,609
2004	1,084	183	1,267	4,493

Lane departure crashes accounted for **27% of all fatal and incapacitating injury crashes in Massachusetts** between 2002 and 2004.

Object Collided With

Massachusetts Incapacitating Injury Run Off Road Crashes by Object Collided With, 2002-2004*

As illustrated in the pie chart, **trees and utility poles** are the most common objects collided with for incapacitating injury run off road crashes, accounting for 52% of these crashes.



MA Incapacitating Injury Single Vehicle Run Off Road Crashes by Functional Classification and Object Struck, 2002-2004***

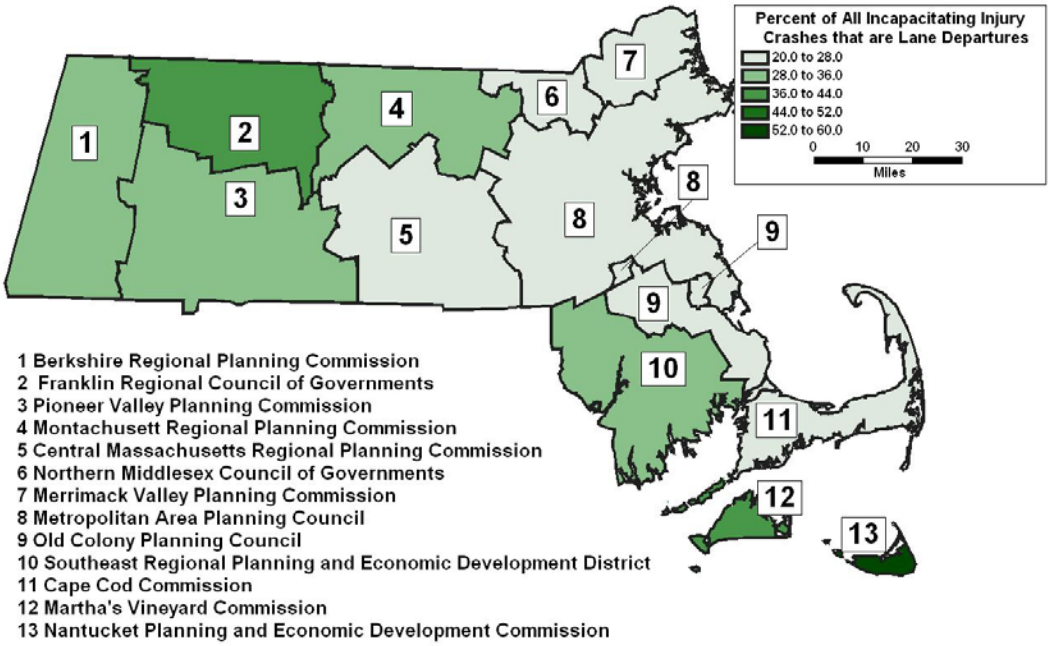
Object Collided With	Interstate	Rural Principal Arterials or Urban Other Expressways	Rural Minor Arterial or Urban Principal Arterial	Urban Minor Arterial or Rural Major Collector	Urban Collector or Rural Minor Collector	Local
Tree	9%	27%	20%	26%	31%	38%
Utility Pole/ Post	2%	10%	37%	38%	37%	27%
Guardrail/ Median Barrier/ Crash Cushion	62%	37%	10%	4%	7%	1%
Curb/ Ditch/ Embankment	23%	23%	23%	21%	17%	21%
Other	4%	3%	9%	10%	7%	12%
Total	100%	100%	100%	100%	100%	100%

On lower level roads (i.e. collector and local roads), trees or utility poles/posts were the most common object collided with. On higher level roads (i.e. Interstates and arterials), however, guardrails/median barriers/crash cushions as well as curbs/ditches/embankments were the most common object collided with. It is also interesting to note that curbs/ditches/embankments consistently account for about 20% of incapacitating

*2004 non-fatal crash data based on crash reports submitted to Registry of Motor Vehicles prior to 7/16/2005.
**Based on geocoded crashes only. More information on geocoding can be found on the back cover.

LOCATION CHARACTERISTICS

Percent of All Incapacitating Injury Crashes that are Lane Departures, 2002-2004*



Martha's Vineyard and Nantucket had a very small number of incapacitating injury lane departure crashes as well as a very small number of incapacitating injury crashes overall. This should be kept in mind when considering the "high" percentage of incapacitating injury lane departure crashes for these two regions.

This map is based on all incapacitating injury lane departure crashes reported to the Registry of Motor Vehicles, not just those that were successfully geocoded. For more information on geocoded crashes, please see the back cover.

Incapacitating Injury Lane Departure Crashes per 100 Lane Miles, 2002-2004*

The table below shows the number of incapacitating injury lane departure crashes normalized by the number of lane miles in each RPA. This provides information for examining and comparing RPAs accounting for the varying number of lane miles within each RPA.

	Incapacitating Injury Lane Departure Crashes	Lane Miles	Rate of Incapacitating Injury Lane Departure Crashes per 100 Lane Miles
1 Berkshire Regional Planning Commission	88	3,455.54	2.55
2 Franklin Regional Council of Governments	56	2,775.43	2.02
3 Pioneer Valley Planning Commission	273	8,416.75	3.24
4 Montachusett Regional Planning Commission	135	3,832.92	3.52
5 Central Massachusetts Regional Planning Commission	302	7,197.10	4.20
6 Northern Middlesex Council Of Governments	143	2,640.21	5.42
7 Merrimack Valley Planning Commission	138	3,349.77	4.12
8 Metropolitan Area Planning Council (MAPC)***	1,147	23,186.61	4.95
9 Old Colony Planning Council (OCPC)***	218	3,351.39	6.50
10 Southeast Regional Planning & Economic Development District	411	7,300.80	5.63
11 Cape Cod Commission	109	4,930.13	2.21
12 Marthas Vineyard Commission	8	323.13	2.48
13 Nantucket Planning & Economic Development Commission	4	207.29	1.93

*2004 non-fatal crash data based on crash reports submitted to Registry of Motor Vehicles prior to 7/16/2005.
*** The number of crashes and lane miles for MAPC includes Stoughton and crashes and lane miles for OCPC include Pembroke.

ROADWAY CHARACTERISTICS

Roadway Jurisdiction**

MA Incapacitating Injury Lane Departure Crashes by Jurisdiction, 2002-2004***

	Incapacitating Injury Lane Departure Crashes	Rate per 100 Lane Miles
Massachusetts Highway Department	**679**	**7.79**
Massachusetts Turnpike Authority	**48**	**6.98**
Department of Conservation and Recreation	35	5.61
City or Town Accepted Road	1,452	2.67
Federal Park or Forest	1	0.46
Unaccepted by city or town	19	0.33
State Park or Forest	1	0.26

The jurisdictions with the highest rates of incapacitating injury lane departure crashes per 100 lane miles were **Massachusetts Highway Department** and **Massachusetts Turnpike Authority**.

Although the rate per 100 lane miles is not high for city or town accepter roads, when considering frequency, 65% of incapacitating injury lane departure crashes took place on city or town accepted roads.

Functional Classification**

The rate per 100 million vehicle miles traveled for incapacitating injury lane departure crashes on **urban collector/ rural minor collector** roadways was almost two times higher than the rate for the next highest functional class of roadways.

It should also be noted that while urban collector/rural minor collector roadways accounted for only 6% of annual vehicle miles traveled, 17% of incapacitating injury lane departure crashes occurred on these roadways.

MA Incapacitating Injury Lane Departure Crashes by Functional Classification, 2002-2004***

	Incapacitating Injury Lane Departure Crashes	Rate per 100 Million Vehicle Miles Traveled
Interstate	300	0.63
Rural Principal Arterial or Other Urban Expressway	208	1.13
Rural minor arterial or urban principal arterial	336	0.94
Urban minor arterial or rural major collector	634	2.25
Urban collector or rural minor collector	**371**	**4.14**
Local	386	1.77

Roadway Alignment

Curved roadway alignments accounted for nearly 28% of lane departure fatal crashes and only 18% of all fatal crashes.

MA Fatal Crashes by Roadway Alignment, 2002-2004

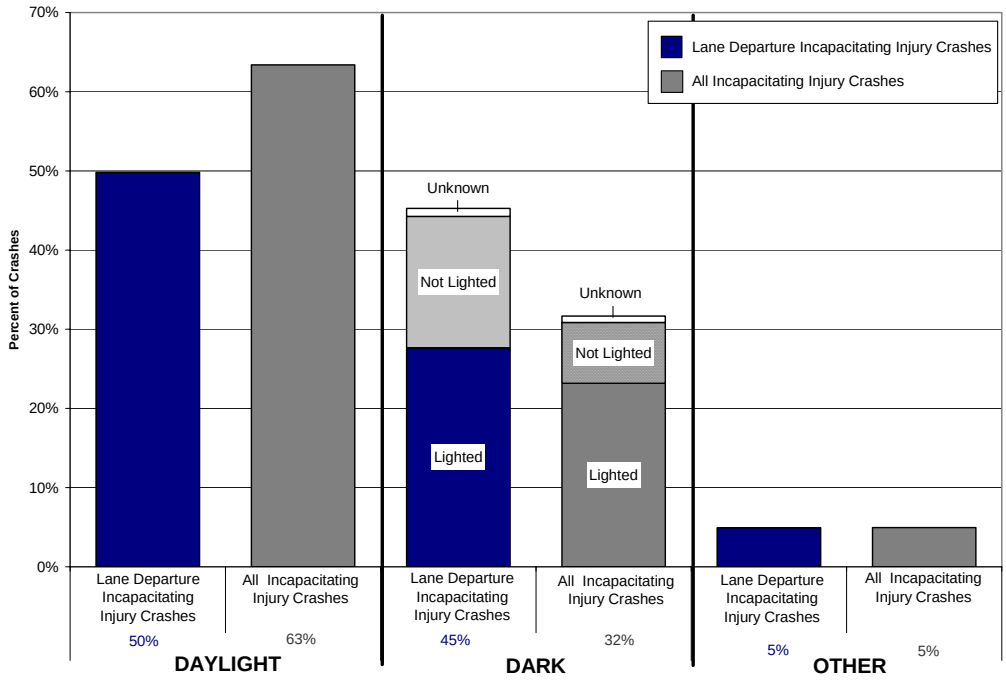
	Lane Departure Fatal Crashes	All Fatal Crashes
Straight	63%	75%
Curved	**28%**	**18%**
Unknown	9%	7%

*2004 non-fatal crash data based on crash reports submitted to Registry of Motor Vehicles prior to 7/16/2005.
**Based on geocoded crashes only. More information on geocoding can be found on the back cover.

ROADWAY CHARACTERISTICS

Lighting Conditions

Percent of MA Incapacitating Injury Lane Departure/ All Incapacitating Injury Crashes by Lighting Conditions, 2002-2004*



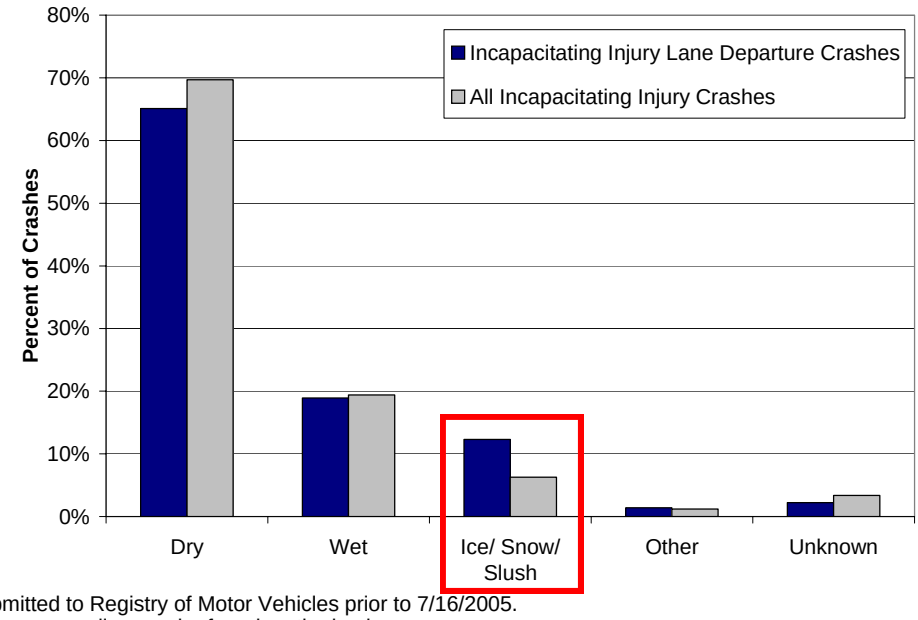
A greater percentage of incapacitating injury lane departure crashes, where lighting condition was reported, occurred in **dark light conditions** when compared to all incapacitating injury crashes (45% vs 32%).

When considering crashes that occurred on dark roadways, incapacitating injury lane departure crashes were two times more likely to be on **unlighted roadways** than all incapacitating injury crashes.

Road Surface

Percent of Incapacitating Injury Lane Departure/ All Incapacitating Injury Crashes by Road Surface Conditions, 2002-2004*

The percent of incapacitating injury lane departure crashes that occurred on **ice/snow/ slush** was twice that of all incapacitating injury crashes.

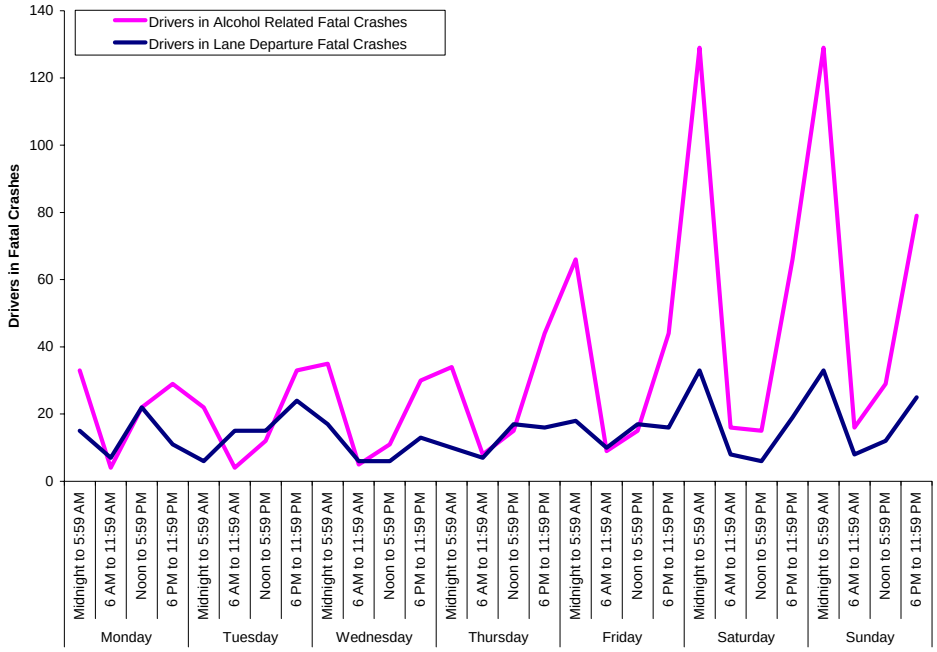


*2004 non-fatal crash data based on crash reports submitted to Registry of Motor Vehicles prior to 7/16/2005.
**Based on geocoded crashes only. More information on geocoding can be found on the back cover.

BEHAVIORAL CHARACTERISTICS

Alcohol-Related Crashes

Drivers in Alcohol-Related and Lane Departure Fatal Crashes, 2002-2004



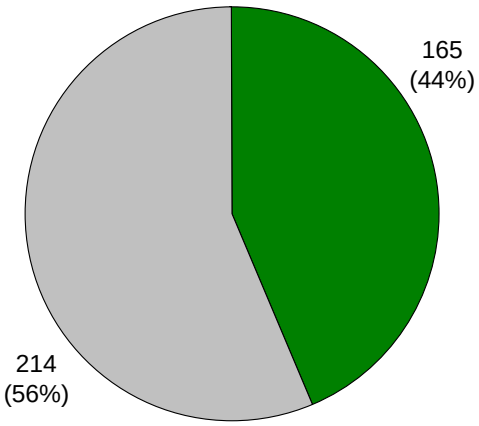
Drivers involved in **alcohol-related fatal crashes** and lane departure fatal crashes follow similar trends for time of day and day of week. Although there is no available data on alcohol in lane departure crashes, these similar trends allow us to infer that there is likely an overlap between the characteristics for lane departure fatal crashes and alcohol-related fatal crashes.

Speed-Related Crashes

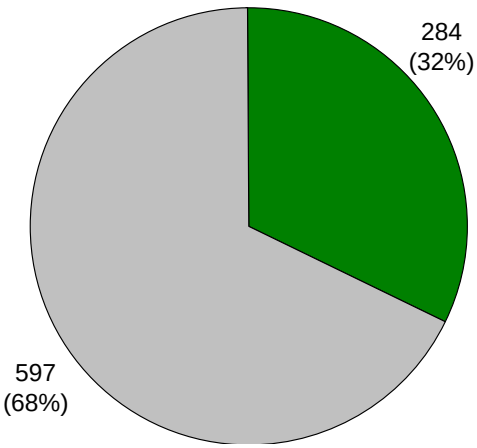
Speed-Related Fatal Crashes in Massachusetts, 2003-2004

In 2003 and 2004, **speeding was a factor in 44% of lane departure fatal crashes** compared to only 32% of all fatal crashes.

Massachusetts Lane Departure Fatal Crashes, 2003-2004



All Massachusetts Fatal Crashes, 2003-2004



Speed Related Fatal Crashes

Non Speed Related Fatal Crashes

ADDITIONAL RESOURCES

For further information regarding the prevalence and importance of lane departure crashes as a safety issue at the national level, consider the following resources.

FHWA Safety: Road Departure Safety

http://safety.fhwa.dot.gov/roadway_dept/

This website provides links to information on roadside hardware guidance, rumble strips, work zone safety, and night time visibility. In addition information on road departure safety countermeasures, strategic highway safety plan implementation guides, and plans for improving roadside safety can be found on this site.

AASHTO Strategic Highway Safety Plan-Goal 15: Keeping Vehicles on Roadway

http://safety.transportation.org//elements.aspx?cid=hws&gid=15

This website provides links to recommended strategies included in the AASHTO Strategic Highway Safety Plan for keeping vehicles on the roadway. Strategies include pavement markings, shoulder rumble strips, improved design, speed management, and roadway maintenance.

NCHRP Implementation Guides: Run Off Road and Head On Collisions

Run Off Road Collisions: http://safety.transportation.org//elements.aspx?cid=27

Head On Collisions: http://safety.transportation.org//elements.aspx?cid=25

NCHRP has created a series of guides to assist state and local agencies in reducing injuries and fatalities in targeted emphasis areas. Each guide includes a brief introduction, a general description of the problem, the strategies/countermeasures to address the problem, and a model implementation process.

FOR MORE INFORMATION

MA Lane Departure Lead State Initiative

Bonnie Polin
Massachusetts Highway Department
Bonnie.polin@mhd.state.ma.us
(617) 973-7991

MA Lane Departure Data Analyses

Heather Rothenberg
University of Massachusetts Traffic Safety Research Program (UMassSafe)
hrothenb@acad.umass.edu
(413) 577-4304

Lane Departure Definitions

Massachusetts Crash Data System (CDS) Definition

Lane Departure
- **Multi Vehicle Run Off Road**
  - **Head On with Motor Vehicle in Traffic**
    - Manner of Collision = Head On
    - AND
    - First Harmful Event = Collision with motor vehicle in traffic
  - OR
  - **Collision with parked vehicle**
    - First Harmful Event = Collision with parked motor vehicle
- OR
- **Single Vehicle Run Off Road**
  - **Single Vehicle ROR A**
    - Event Sequence 1 = collision with curb, collision with ditch, collision with embankment, collision with fence, collision with guardrail, collision with highway traffic sign post, collision with impact attenuator/crash cushion, collision with light pole or other post/support, collision with mail box, collision with median barrier, collision with other fixed object (wall, building, tunnel, etc), collision with overhead sign support, collision with tree, collision with unknown fixed object, collision with utility pole, cross median or centerline, ran off road left, or ran off road right
    - AND
    - Number of vehicles = 1
  - OR
  - **Single Vehicle ROR B**
    - Event Sequence 1 NOT = collision with curb, collision with ditch, collision with embankment, collision with fence, collision with guardrail, collision with highway traffic sign post, collision with impact attenuator/crash cushion, collision with light pole or other post/support, collision with mail box, collision with median barrier, collision with other fixed object (wall, building, tunnel, etc), collision with overhead sign support, collision with tree, collision with unknown fixed object, collision with utility pole, cross median or centerline, ran off road left, or ran off road right
    - AND
    - First Harmful Event = collision with curb, collision with ditch, collision with embankment, collision with guardrail, collision with median barrier, collision with other light pole or other post/support, collision with tree, collision with unknown fixed object, or collision with utility pole
    - AND
    - Number of vehicles = 1

AND

Incapacitating Injury Crash
- Fatalities = 0
- AND
- Incapacitating Injuries NOT = 0

AND

Non Intersection
- Roadway intersection type NOT = driveway, five point or more, four-way intersection, T-intersection, Y-intersection

Fatality Analysis Reporting System (FARS) Definition

Lane Departure
- **Multi Vehicle Run Off Road**
  - **Head On with Motor Vehicle in Traffic**
    - Manner of Collision = Front to Front (includes head-on)
    - AND
    - First Harmful Event = Motor Vehicle in Transport
  - OR
  - **Collision with parked vehicle**
    - First Harmful Event = Parked motor vehicle
- OR
- **Single Vehicle Run Off Road**
  - **Single Vehicle ROR A**
    - First Harmful Event = boulder, building, impact attenuator/crash cushion, bridge pier or abutment, bridge parapet end, bridge rail, guardrail, concrete traffic barrier, other longitudinal barrier type, highway/traffic sign post/sign, overhead sign support, luminaire/light support, utility pole, other post/pole/support, culver, curb, ditch, embankment-earth, embankment-rock/stone/concrete, embankment-material type unknown, fence, wall, fire hydrant, shrubbery, tree, other fixed object, traffic signal support/signal, snowbank
    - AND
    - Number of vehicle form submitted = 1
  - OR
  - **Single Vehicle ROR B**
    - First Harmful Event = blank, overturn, fire/explosion, immersion, gas inhalation, fell/jumped from vehicle, injured in vehicle, other non-collision, pedestrian, pedalcycle, railway train, animal, motor vehicle in transport, motor vehicle in transport in other roadway, parked motor vehicle, other type non-motorist, thrown or falling object, other object (not fixed), pavement surface irregularity, transport device used as equipment, vehicle or occupant struck or run over by own vehicle, ridden animal or animal drawn conveyance, bridge overhead structure, unknown
    - AND
    - Most Harmful Event = boulder, building, impact attenuator/crash cushion, bridge pier or abutment, bridge parapet end, bridge rail, guardrail, concrete traffic barrier, other longitudinal barrier type, highway/traffic sign post/sign, overhead sign support, luminaire/light support, utility pole, other post/pole/support, culver, curb, ditch, embankment-earth, embankment-rock/stone/concrete, embankment-material type unknown, fence, wall, fire hydrant, shrubbery, tree, other fixed object, traffic signal support/signal, snowbank
    - AND
    - Number of vehicle forms submitted = 1
- AND
- **Non Intersection**
  - Relation to Junction = blank, non junction (non interchange), entrance/exit ramp related, rail grade crossing, crossover related, non interchange driveway access related, unknown non interchange, entrance/exit ramp related (interchange area), crossover related (interchange area), other location in interchange, unknown interchange area, unknown

Geocoding Information

Analyses that were based solely on geocoded crashes (functional classification and jurisdiction) drew only from crashes that had crash locations identified by the Massachusetts Highway Department geocoder. Of the 3,032 incapacitating injury lane departure crashes that occurred in Massachusetts between 2002 and 2004, 2,235 were successfully geocoded (74%). The table below shows successfully geocoded incapacitating injury lane departure crashes by RPA.

Regional Planning Agency	Geocoded Inacpacitating Injury Lane Departure Crashes	Incapacitating Injury Lane Departure Crashes	% Incapacitating Injury Lane Departure Crashes Successfully Geocoded
Berkshire County Regional Planning Commission	49	88	56%
Cape Cod Commission	70	109	64%
Central Massachusetts Regional Planning Commission	220	302	73%
Franklin County Planning Department	36	56	64%
Belongs to Both MAPC and OCPC	30	36	83%
Marthas Vineyard Commission	2	8	25%
Merrimack Valley Planning Commission	102	138	74%
Metropolitan Area Planning Council	842	1,128	75%
Montachusett Regional Planning Commission	96	135	71%
Nantucket Planning & Economic Development Commission	2	4	50%
Northern Middlesex Council Of Governments	116	143	81%
Old Colony Planning Council	166	201	83%
Pioneer Valley Planning Commission	205	273	75%
Southeast Regional Planning & Economic Development	299	411	73%
Massachusetts	**2,235**	**3,032**	**74%**

APPENDIX D

CASE STUDY: Arizona SR 264 Burnside Junction to Summit-Safety Improvement Evaluation

Appendix D is a case study prepared by FHWA that describes how Arizona used the Performance-Based Practical Design approach to evaluate two roadside departure crash countermeasures—widening shoulders and improving superelevation.

Publication No. FHWA-HIF-15-014

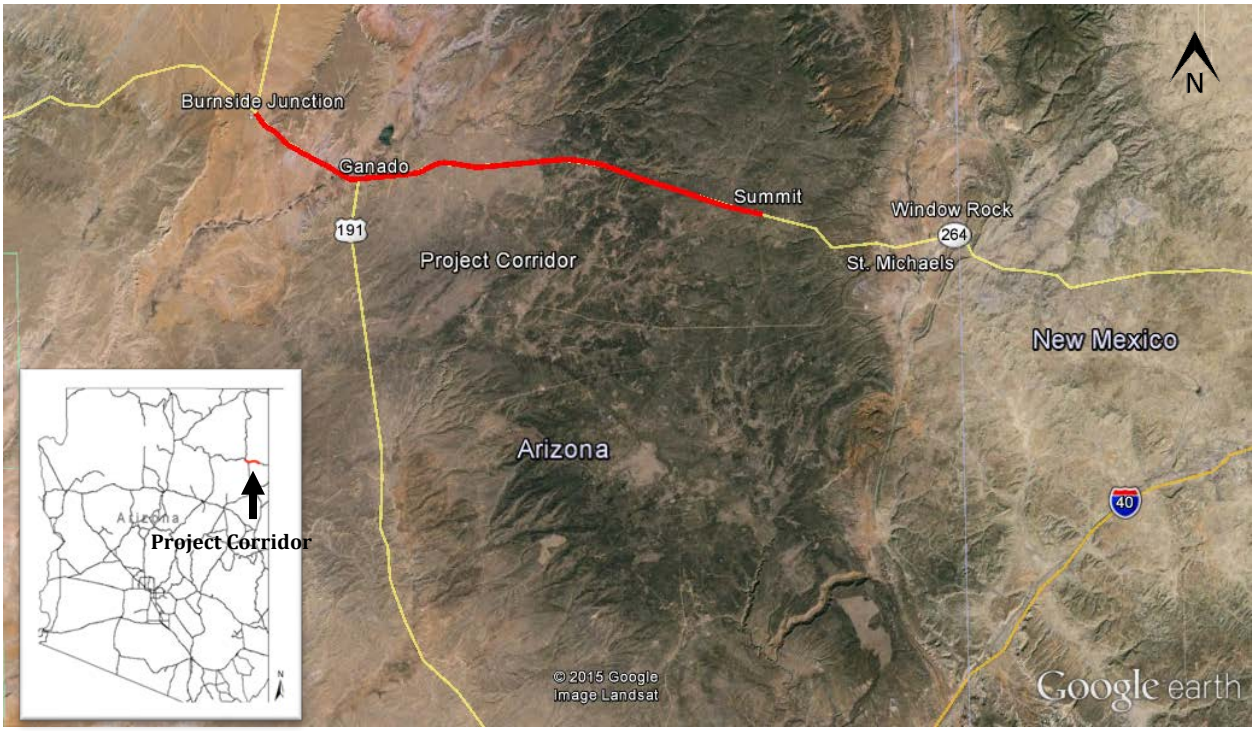
Case Study: Arizona SR 264 Burnside Junction to Summit - Safety Improvement Evaluation

Agency: Arizona Department of Transportation (ADOT)
Location: Navajo County, Arizona
Region: Southwest Region
Setting: Rural

Overview

The Arizona Department of Transportation (ADOT) Traffic Safety Section recognized that a significant portion of Arizona's fatal crashes were of the run-off-roadway crash type along rural two-lane highways, as is typical for most states with significant mileage of rural highways. The ADOT Traffic Safety Section took a systemic approach and reviewed two-lane rural highways with a higher potential for run-off-roadway crashes. One of the priority corridors for shoulder widening as a federal Highway Safety Improvement Program (HSIP) funded project was State Route 264 (SR 264) from Burnside Junction to Summit in Northern Arizona. This is a 24.55 mile corridor from Milepost (MP) 441.19 in Burnside Junction to MP 465.74 at the Summit. This section of SR 264 is located in Navajo County, Arizona, within the ADOT Holbrook District and is shown in Figure 1. SR 264 through this section is classified as a rural minor arterial and runs east-west. The area of interest is currently a two-lane rural highway, with intermittent right- and left-turn lanes and passing lanes.

Figure 1 – Vicinity Map



Source: Google Earth

Performance-Based Practical Design is a decision making approach that helps agencies better manage transportation investments and serve system-level needs and performance priorities with limited resources. Performance-Based Practical Design can also be articulated as modifying a traditional design approach to a "design up" approach where transportation decision makers exercise engineering judgment to build up the improvements from existing conditions to meet both project and system objectives. Performance-Based Practical Design uses appropriate performance-analysis tools, considers both short and long term project and system goals while addressing project purpose and need. The following case study on SR 264 in Arizona is an example of developing a performance-based practical design for the shoulder width and project segmentation.

During the project scoping evaluation by the ADOT Traffic Safety Section, it was determined that the project would be split into two separate segments which are intended to be prioritized based on the potential reduction of the total number of crashes. The mile post (MP) limits of the two segments are as follows:

- Segment I (MP 441.19 – MP 452.00)
- Segment II (MP 452.00 – MP 465.74)

Using the American Association of State & Highway Transportation Officials (AASHTO) Highway Safety Manual (HSM), 2010, Predictive Method, expected total crashes were estimated for the purpose of evaluating the effect of:

- Design alternatives; and
- Segment Prioritization

The effect on traffic safety was analyzed for the following improvement alternatives:

- Shoulder Widening Alternative A - Widening the existing 1-foot shoulders to 5 feet;
- Shoulder Widening Alternative B - Widening the existing 1-foot shoulders to 8 feet; and
- Improving superelevation to bring into compliance with AASHTO recommendations.

The following provides a summary of the three traffic safety alternatives:

Shoulder Widening Alternative A – Widen Existing Roadway to 34 feet

The purpose of Alternative A is to widen the existing roadway to 34 feet to provide 5-foot shoulders. The proposed improvements would widen the existing 1-foot shoulders to 5-foot shoulders. The existing travel lane width would remain 12 feet. The improvements would include adding centerline and shoulder rumble strips, flattening side slopes, installing guardrail, extending drainage structures and providing delineators and recessed pavement markers. The original intent was for this alternative to be 32 feet wide with 4-foot shoulders; however it was widened to 5-foot shoulders to be able to meet the FHWA recommendation for a 4-foot bikeable width outside of the rumble strip.

Shoulder Widening Alternative B – Widen Existing Roadway to 40 feet

The purpose of Alternative B is to widen the existing roadway to 40 feet to provide the standard shoulder width. The proposed improvements would widen the existing 1-foot shoulders to 8-foot shoulders. The existing travel lane width would remain 12 feet. The improvements would include adding centerline and shoulder rumble strips, flattening side slopes, installing guardrail, extending drainage structures, and providing delineators and recessed pavement markers.

Superelevation Improvement Consideration

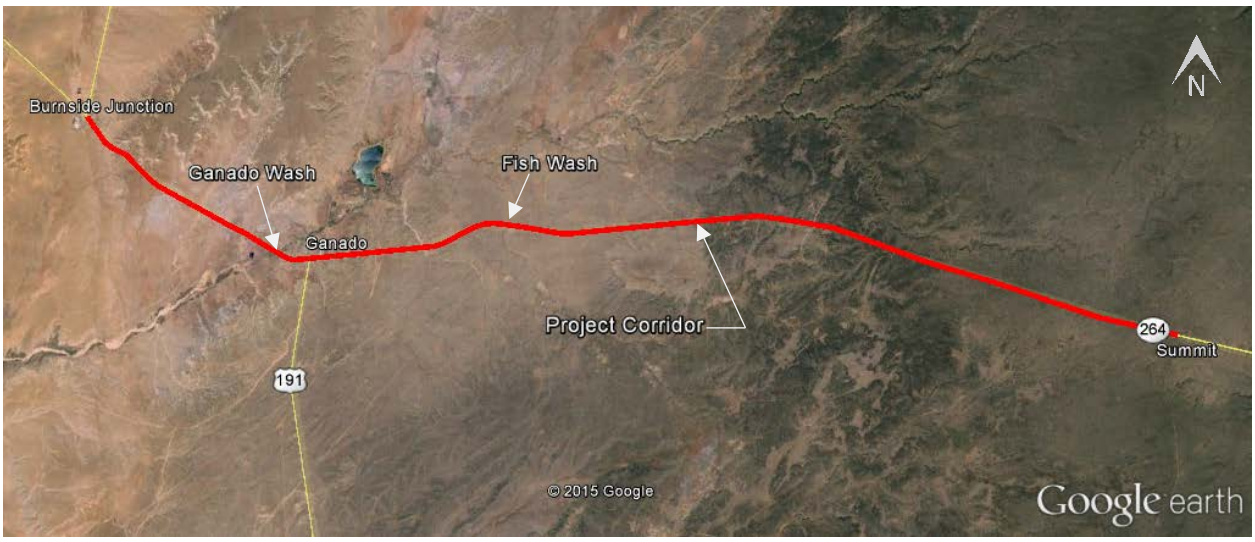
An additional consideration is to improve the superelevation on horizontal curves located within the project limits to bring the cross slope into compliance with the AASHTO recommended minimum superelevation rates. The superelevation improvements were evaluated independently of any additional improvements for the purpose of developing a benefit-cost ratio.

Approach

Analysis of Existing Conditions

SR 264 is an undivided highway consisting of one 12-foot travel lane in each direction with approximate 1-foot paved shoulders on each side. Climbing lanes are present for eastbound travel between MP 441.2 and MP 442.6, westbound travel between MP 442.6 and MP 443.8, and eastbound travel between MP 447.6 and MP 448.8. There are existing turn lanes at MP 446.3, 446.6, 446.9 (US 191), 448.3 and 452.1. There are four major structures located within the project limits including one structural plate pipe arch, one pedestrian overpass, and two bridges at Fish Wash and Ganado Wash. There is existing guardrail at Ganado Wash Bridge (MP 446.20), at MP 447.0, and at Fish Wash Bridge (MP 451.30). An aerial view of the location of interest is shown in Figure 2.

Figure 2 – Aerial View of Project



Source: Google Earth

As reported by the Data Team of the Multimodal Planning Division (MPD), the 2010 Average Annual Daily Traffic (AADT) within the project limits varies between 4,100 and 6,500 vehicles per day as shown in Table 1.

Table 1: 2010 AADT

SR 264	2010 AADT (vehicles per day)
MP 441.02-MP 446.18	5,010
MP 446.18-MP 446.91	6,429
MP 446.91-MP 448.37	5,199
MP 448.37-MP 475.50	4,102

Crash data for the most recent 4-year period (2007-2010) were used in this evaluation since 2011 crash data was not available to use at the time of this study. Tables 2 and 3 below summarize the total number of crashes, as well as the severity and manner of collision.

Table 2: Crash Severity, 2007-2010

Severity	Number
Fatal	6
Incapacitating Injury	3
Non-Incapacitating Injury	1
Possible Injury	24
No Injury (PDO)	22
Total	*56*

Table 3: Manner of Collision, 2007-2010

Manner of Collision	Number
Head On	2
Left Turn	3
Rear End	13
Angle (Other than Left Turn)	5
Sideswipe (Opposite Direction)	2
Sideswipe (Same Direction)	4
Single Vehicle	27
Total	*56*

A total of 56 crashes were found to be associated to SR 264 within the project limits between 2007 and 2010. The average annual crash frequency is 14 crashes per year.

As reported by the Data Team of the MPD, the 2036 Projected AADT for SR 264 within the project limits varies between 5,400 and 12,150 vehicles per day as shown in Table 4.

Table 4: 2036 Design Year AADT

SR 264	2036 Projected AADT (vehicles per day)
MP 441.02-MP 446.18	9,900
MP 446.18-MP 446.91	12,150
MP 446.91-MP 448.37	7,350
MP 448.37-MP 475.50	5,400

A safety analysis was performed by ADOT's consultants for this project using the procedures outlined in the *Highway Safety Manual* (HSM). The HSM provides guidance on how to analyze highway sections that are reasonably homogeneous with respect to key variables such as traffic volume, highway cross-section, highway classification, and surrounding geometric conditions. The proposed improvements are not anticipated to impact traffic operations, since all alternatives have one travel lane in each direction. Therefore a traffic operational analysis was not performed for this study.

Safety Analysis

Implementation of the Predictive Method requires the development of three main parts: a Safety Performance Function (SPF), Crash Modification Factors (CMFs), and a local calibration factor (C). The SPF uses roadway geometry, roadway characteristics, and traffic conditions to determine a base condition for a particular category of highway. For the purpose of this study, SR 264 falls under the category of a rural two-lane, two-way road as defined in Chapter 10 of Part C of the HSM. CMFs are then applied to the SPF to create a site-specific function that more accurately reflects the existing or proposed conditions of the roadway. Finally, a calibration factor can be applied to account for jurisdictional/regional variations in climate, driver population, etc. At the time of this study, ADOT has not developed a local calibration factor. So, a local calibration factor was not applied.

Table 5 shows the base parameters of the SPF for a Rural Two-Lane, Two-Way Road along with the parameters used in developing the SPF for the existing and proposed conditions. Notable variations from the base condition include the shoulder width, roadside hazard rating, and centerline rumble strips.

Table 5: Base Parameters for the SPF for Rural Two-Lane, Two-Way Road

Roadway Element	Existing SR 264 (1 foot Shoulder)	HSM Base Condition	Alternative A (5 foot Shoulder)	Alternative B (8 foot Shoulder)
Lane width	12 feet	12 feet	12 feet	12 feet
Shoulder width	1 foot	6 feet	5 feet	8 feet
Shoulder type	Paved	Paved	Paved	Paved
Roadside hazard rating	6	3	2, except 4 for guardrail sections	2, except 4 for guardrail sections
Driveway Density	Per survey & Holbrook District turnout database	≤ 5 per mile	Per survey & Holbrook District turnout database	Per survey & Holbrook District turnout database
Horizontal curves: length, radius, and presence or absence of spiral transitions	Per best-fit alignment	None	Per best-fit alignment (match existing)	Per best-fit alignment (match existing)
Horizontal curves: Superelevation	Per as-builts & survey	None	Per as-builts & survey (match existing)	Per as-builts & survey (match existing)
Grades	Per as-builts & survey	≤ 3%	Per as-builts & survey (match existing)	Per as-builts & survey (match existing)
Centerline rumble strips	None	None	Present	Present
Passing lanes	Per survey	None	Per survey (match existing)	Per survey (match existing)
Two-way left-turn lanes	Per survey	None	Per survey (match existing)	Per survey (match existing)
Lighting	Present @ US 191 Intersection	None	Present @ US 191 Intersection (match existing)	Present @ US 191 Intersection (match existing)
Automated speed enforcement	None	None	None	None

Utilizing the Interactive Highway Safety Design Model (IHSDM) software and the parameters listed above, the Predictive Method was applied to each alternative to calculate a predicted total number of crashes for the study period of 2016 to 2036. An expected total number of crashes was calculated by including site specific crash data in the predictive analysis using the Empirical Bayes (EB) Method.

Existing Conditions with Projected AADT Values

Using the methodology detailed above, an expected total number of crashes was calculated for SR 264 from Burnside Junction to Summit, as shown in Table 6.

Table 6: Existing Conditions Expected Crashes

Crash Severity Level	2016 2036 Expected Total Number of Crashes
Total	636.38
Fatal and Injury (FI)	283.40
Property Damage Only (PDO)	352.98

The expected total number of crashes over the 20-year analysis period is 636.38 crashes, which equates to a crash frequency of 31.82 crashes per year.

Analysis of Roadside Design Alternatives

Proposed Conditions with Projected AADT Values

Using the same methodology as before, an expected number of crashes was calculated for SR 264 for each of the alternatives previously mentioned and is summarized in Table 7.

Table 7: Expected Crashes with Proposed Shoulder Widening

Crash Severity Level	2016 2036 Expected Total Number of Crashes		
	Existing Conditions	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders
Total	636.38	531.58	504.16
Fatal and Injury (FI)	283.40	230.45	216.80
Property Damage Only (PDO)	352.98	301.13	287.36
Reduction in Total Crashes over Existing Conditions	-	104.80	132.22

The proposed improvements for alternatives A and B respectively reduce the expected number of crashes compared to the existing conditions by 104.80 and 132.22 crashes over the 20-year analysis period. The corresponding Crash Modification Factors (CMFs) for Alternatives A and B are approximately 0.84 (16% reduction) and 0.79 (21% reduction), respectively.

Superelevation Improvements with Projected AADT Values

The Predictive Method was also used to evaluate the effect of improving superelevation rates on the total expected number of crashes. The analysis was performed assuming that the superelevation improvements were being made independent of all other improvements. The results of the superelevation analysis are shown in Table 8.

Table 8: Expected Crashes with Proposed Superelevation

Crash Severity Level	2016 2036 Expected Total Number of Crashes	
	Existing Conditions	Superelevation
Total	636.38	635.26
Fatal and Injury (FI)	283.40	282.71
Property Damage Only (PDO)	352.98	352.55
Reduction in Total Crashes over Existing Conditions	-	1.12

The effect of bringing existing superelevation rates into compliance with the AASHTO minimum values reduced the total number of expected crashes by 1.12 crashes over the 20-year analysis period. This reduction corresponds to a rounded CMF of 1.00 (0.2% reduction).

Benefit-Cost Ratio

Crash Severity Proportions

In order to perform a benefit-cost ratio Analysis in accordance with the procedures contained in the *Arizona Highway Safety Improvement Program Manual*, 2010, it was required that the total expected crash frequency be broken into five severity levels:

- Fatal
- Incapacitating injury
- Non-incapacitating injury
- Possible injury
- Property damage only (PDO)

Table 10-3 in the HSM provides default proportions for crash severity. The HSM values are based on State of Washington data (2002-2006). The project being located within the Navajo Nation, it was believed that it would be more appropriate to develop proportions based on data from this region. In order to calculate the necessary proportions, a data query of crashes on three rural two-lane, two-way state highways within the Navajo Nation and the Hopi Tribe in Arizona was performed. The segments queried were:

- SR 264 from US 160 to the State Border (approximately 150 roadway miles)
- US 160 from US 89 to the State Border (approximately 160 roadway miles)
- US 191 from I-40 to US 160 (approximately 130 roadway miles)

Five years of crash data were used (2007-2011). The total number of crashes for each severity level were determined and the percentages of the total were calculated. Table 9 illustrates the crash severity percentages used in the analysis.

Table 9: Navajo and Hopi State Highway System Rural Two-Lane Two-way Roadway Segment Crashes (2007-2011)

Severity Level	Percent of Total
Fatal	*12.4%*
Incapacitating Injury	*4.9%*
Non-Incapacitating Injury	*13.0%*
Possible Injury	*23.2%*
Property Damage Only (PDO)	*46.5%*

It should be noted that the percent of fatal crashes in this tribal region is significantly higher and the percent of property damage only crashes is much lower than the data presented in the Highway Safety Manual for rural two-lane, two-way roadways. The contributing factors resulting in this significant difference is unknown at this time. Likewise, it is unknown if these proportions may be applicable to all two-lane, two-way roadways in Arizona. The above proportions should not be used for other regions of Arizona without querying crash data from the specific region under study.

These percentages were then multiplied by the total expected crash frequencies derived from the Predictive Method results summarized earlier in this report. Annual averages were calculated by evenly distributing the total crashes over the 20-year analysis period.

8-foot Shoulders versus 5-foot Shoulders

A benefit-cost ratio analysis was performed in order to select the alternative that is expected to provide the most safety benefit with respect to cost. The estimates for each alternative included pavement, pipe extensions, and earthwork as the three major items quantified for cost. These cost estimates resulted in a total project cost of approximately $26.3 million for 8-foot shoulders and $16.5 million for 5-foot shoulders. For the sole purpose of comparing alternatives, an annual maintenance cost of $0 was assumed for each alternative. Tables 10 and 11 display the calculations of the benefit-cost ratios for the 8-foot shoulder and 5-foot shoulder, respectively.

Table 10: Benefit-Cost Ratio Tabulation for 8-foot Shoulder

Severity	Benefits				
	Annual Average	Estimated CRF Reduction	Total Reduction	Unit Cost	Annual Benefit
Fatal	3.95	21%	0.83	$5,800,000	$4,806,228
Incapacitating Injury	1.56	21%	0.33	$400,000	$130,956
Non Incapacitating Injury	4.14	21%	0.87	$80,000	$69,485
Possible Injury	7.38	21%	1.55	$42,000	$65,109
No Injury	14.80	21%	3.11	$4,000	$12,429
Unknown	0.00	0%	0.00	$4,000	$0
				Total Annual Benefits	$5,084,207

Costs	Annual Costs
Total Construction Costs	$26,300,000
Project Life (years)	20
Interest Rate (%)	8%
Capital Recovery Factor	0.1019
Annual Construction Cost	$2,678,713
Annual Maintenance Cost	0
Total Annual Costs	$2,678,713

Benefit / Cost		
Annual Benefit	Annual cost	Benefit-Cost Ratio
$5,084,207	$2,678,713	1.90

CRF = Crash Reduction Factor

Table 11: Benefit-Cost Ratio Tabulation for 5-foot Shoulder

Severity	Annual Benefit Tabulation				
	Annual Average	Estimated CRF Reduction	Total Reduction	Unit Cost	Annual Benefit
Fatal	3.95	16%	0.63	$5,800,000	$3,661,888
Incapacitating Injury	1.56	16%	0.25	$400,000	$99,776
Non Incapacitating Injury	4.14	16%	0.66	$80,000	$52,941
Possible Injury	7.38	16%	1.18	$42,000	$49,607
No Injury	14.80	16%	2.37	$4,000	$9,469
Unknown	0.00	0%	0.00	$4,000	$0
				Total Annual Benefits	$3,873,681

Costs	Annual Costs
Total Construction Costs	$16,500,000
Project Life (years)	20
Interest Rate (%)	8%
Capital Recovery Factor	0.1019
Annual Construction Cost	$1,680,561
Annual Maintenance Cost	0
Total Annual Costs	$1,680,561

Benefit / Cost		
Annual Benefit	Annual cost	Benefit-Cost Ratio
$3,873,681	$1,680,561	2.30

It is important to note that both alternatives have a benefit-cost ratio greater than 1.0. Without funding constraints, the preferred alternative would be to widen the shoulder to 8 feet since it would lead to the largest reduction in crashes. However, there is a limited amount of HSIP funding and the intent is to apply safety funds to more effective alternatives. As an example, Table 12 includes the theoretical safety benefit of 5-foot shoulders versus 8-foot shoulders with a set annual budget of $10,000,000 to spend on shoulder widening on roadways with similar conditions. This summary is an oversimplification since the construction cost and benefit are unique to each roadway segment, however this example shows that applying the 5-foot shoulder systemically with an annual budget of $10 million would result in an increase in over 54 miles of shoulder widening and an over $4 million annual safety benefit.

Table 12: Theoretical Systemic Safety Benefit for $10 Million Annual Budget

	Annual Cost per Mile	Number of Miles	Annual Benefit per Mile	Total Benefit
Alternative A: 5-foot Shoulders	$68,455	146.1	$157,787	$23,049,928
Alternative B: 8-foot Shoulders	$109,113	91.7	$207,096	$18,980,036

Superelevation Improvements

A benefit-cost ratio analysis was performed to evaluate the benefit of bringing the existing superelevation into compliance with AASHTO criteria with respect to cost. A planning level cost estimate for bringing the superelevation into compliance was calculated on a per linear foot (LF) basis for two different improvement strategies including full curve reconstruction and differential overlay (See Appendix B). The unit costs for full reconstruction and differential overlay were calculated to be $143.61/LF and $67.08/LF, respectively. These unit costs were then multiplied by the total length of curvature for each curve to estimate the cost of superelevation improvements to each individual curve. For the purpose of this study, it was assumed that 1.9% was the maximum superelevation improvement that could be applied using differential overlay, which corresponds to a 6-inch overlay on the high side of the curve. Using this guideline, it was determined that each curve could be brought to within 1% of AASHTO compliance using only differential overlay. The benefit-cost ratio for each curve using differential overlay is summarized in Table 13.

Table 13: Benefit-Cost Ratio for Superelevation Improvements

	MP	% out of Compliance	CRF	Differential Overlay		
				Annual Benefit	Annual Cost	Benefit Cost Ratio
Curve 1	464.37	1.6%	1.7%	$ 1,119	$ 4,074	0.27
Curve 2	462.06	1.6%	1.4%	$ 373	$ 2,037	0.18
Curve 3	460.47	1.6%	1.6%	$ 773	$ 3,056	0.25
Curve 4	458.39	1.6%	1.2%	$ 1,570	$ 8,148	0.19
Curve 5	456.78	1.6%	1.1%	$ 5,189	$ 11,204	0.46
Curve 6*	454.55	-	0.0%	$ 0	$ 0	0.00
Curve 7	452.44	1.6%	1.2%	$ 5,491	$ 11,204	0.49
Curve 8	450.71	1.6%	1.3%	$ 7,448	$ 26,482	0.28
Curve 9	449.59	1.6%	1.3%	$ 3,407	$ 16,296	0.21
Curve 10	446.49	1.7%	1.1%	$ 1,937	$ 8,148	0.24
Curve 11	445.85	1.6%	0.9%	$ 740	$ 4,074	0.18
Curve 12	445.66	1.6%	0.5%	$ 356	$ 4,074	0.09
Curve 13	445.30	1.4%	0.9%	$ 394	$ 2,037	0.19
Curve 14	445.05	1.6%	0.7%	$ 375	$ 3,056	0.12
Curve 15	443.11	1.6%	1.2%	$ 2,730	$ 12,222	0.22
Curve 16	442.21	2.1%	1.8%	$ 5,690	$ 8,148	0.70
Curve 17	441.79	2.1%	2.0%	$ 4,215	$ 11,204	0.38
			Totals	**$ 41,807**	**$ 135,464**	**0.31**

*Curve 6 is a large radius flat curve

Prioritization of Segments

At the time of this report, the proposed widening improvements were split into two segments of approximately equal construction cost with the following limits:

- Segment I (MP 441.19 – MP 452.00)
- Segment II (MP 452.00 – MP 465.74)

To prioritize the segments, the Predictive Method was applied assuming improvements to each segment were implemented independent of the other. The segment that had the greatest reduction in the expected number of crashes over the entire project limits would be considered for prioritization of construction timing. The segments were evaluated assuming 5-foot shoulders. The results of this analysis are shown in Table 14.

Table 14: Segment Prioritization Expected Crashes

Crash Severity Level	2016 2036 Expected Total Number of Crashes For Entire Project Limits	
	Segment I 5 foot Shoulders, Segment II Existing Conditions	Segment II 5 foot Shoulders, Segment I Existing Conditions
Total	593.09	574.87
Fatal and Injury (FI)	260.70	253.16
Property Damage Only (PDO)	332.39	321.71
Reduction in Total Crashes over Existing Conditions	43.29	61.51
Percent Reduction in Total Crashes over Existing	6.8%	9.7%

Segment II was expected to have a greater reduction in the expected total number of crashes and was considered for receiving priority in construction timing over Segment I based on estimated safety impact. Additional factors were considered in the prioritization decision, such as environmental impacts, right-of-way needs, construction phasing and coordination with other projects. Please note that further modifications in the segmentation were made by ADOT's Statewide Project Management Group based on a number of factors.

Results

Using the aforementioned resources and the HSM Predictive Method, the safety improvements of each alternative were quantified and compared to maintaining the existing conditions of the highway. The expected crash totals over the 20-year analysis period is summarized in Table 15.

Table 15: 2016-2036 Expected Total Number of Crashes

	2016 2036 Expected Total Number of Crashes			
	Existing Conditions	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders	Superelevation Improvements
Total	636.38	531.58	504.16	635.26
Reduction in Total Crashes over Existing Conditions	N/A	104.80	132.22	1.12
Percentage Reduction in Total Crashes over Existing Conditions	N/A	16.5%	20.8%	0.2%

Because of budgetary constraints, the proposed project was split into two separate segments to be constructed independently. As a result, each segment was evaluated for prioritization based on the potential reduction in the total number of crashes over the 20-year analysis period. Segment I included the west half of the project limits between MP 441.19 and MP 452.00. Segment II included the east half of the project limits between MP 452.00 and MP 465.74. Expected total crashes for the entire project limits were estimated for construction of Segment I first, with existing conditions remaining in Segment II. Similarly, expected total crashes for the entire project limits were estimated for construction of Segment II, with existing conditions remaining on Segment I. The results of this analysis are summarized in Table 16.

Table 16: 2016-2036 Expected Total Number of Crashes by Segment

	2016 2036 Expected Total Number of Crashes For Entire Project Limits		
	Existing Conditions	Segment I 5 foot Shoulders with Segment II Existing Conditions	Segment II 5 foot Shoulders with Segment I Existing Conditions
Total	636.38	593.09	574.87
Reduction in Total Crashes over Existing Conditions	N/A	43.29	61.51
Percentage Reduction in Total Crashes over Existing Conditions	N/A	6.8%	9.7%

Segment II was expected to have a greater reduction in the expected total number of crashes and was considered for construction prior to Segment I from a safety perspective.

However, additional factors were considered in the prioritization decision due to the small percentage difference (2.9%) in crash reduction between Segment I and Segment II.

The benefit-cost ratios in Table 17 were calculated using crash severity distributions for Navajo County two-lane two-way state highways in the ADOT Holbrook District and planning level cost estimates for each alternative.

Table 17: Safety Alternative Benefit-Cost Ratio

	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders	Superelevation Improvements
Total Annual Benefit	$3,873,681	$5,084,207	$41,807
Total Annual Cost	$1,680,561	$2,678,713	$135,464
Benefit-Cost Ratio	2.30	1.90	0.31

The benefit-cost ratio for widening to 5-foot shoulders exceeded the benefit-cost ratio for widening to 8-foot shoulders. It is important to note that both shoulder widening alternatives have a benefit-cost ratio greater than 1.0. Without funding constraints, the preferred alternative would have been to widen the roadway to 8-foot shoulders since it would expect to result in the largest reduction in crashes. However, there is a limited amount of HSIP funding and the intent is to apply safety funds to more effective alternatives. Based on this, ADOT decided to move forward with 5-foot shoulders for this project.

Due to additional budget constraints and coordination with adjacent projects, the project was divided into three segments of between six and nine miles each. The projects will be constructed with segments starting from the east. This is consistent with the prioritization of segment crash analysis summarized previously that showed Segment II on the eastern end having a larger crash reduction than Segment I on the western end.

The proposed superelevation improvements for all curves had a reduction of 1.2 crashes over the 20-year project timeframe and an overall benefit-cost ratio of 0.31. In addition, each curve was evaluated individually to determine if there was a benefit for superelevation improvements on a single curve. Due to the minimal crash reduction associated with superelevation, the largest benefit-cost ratio was 0.7 for curve 16 and therefore superelevation improvements are not recommended on any curves.

Strategies Employed

- HSM Part C – Predictive Method
- IHSDM Software

Publications Used/Produced Through this Effort

- Traffic Safety Evaluation, Using the Highway Safety Manual and the Interactive Highway Safety Design Model, SR 264 Burnside Junction to Summit, Kimley-Horn, 2012
- Transportation Research Board Annual Meeting – Poster Session, Application of HSM Predictive Method and IHSDM to Design Decision Making, ADOT and Kimley-Horn 01/2013

Lessons Learned

- The Predictive Method within Part C of the Highway Safety Manual defines a useful procedure to quantify the estimated safety impacts of project alternatives so that more cost-effective decisions can be made on reducing fatal and serious injury crashes.
- The Interactive Highway Safety Design Model was a straight forward software tool that guided us through the quantitative safety analysis consistent with the HSM.

Point of Contact

- Kohinoor Kar, Arizona Department of Transportation (602-712-6857, KKar@azdot.gov)
- Mike Colety, Kimley-Horn (702-862-3609, Mike.Colety@Kimley-Horn.com)

References and Resources

- Highway Safety Manual (HSM). American Association of State Highway and Transportation Officials. Washington, DC. 2010. http://www.highwaysafetymanual.org/Pages/default.aspx
- Interactive Highway Safety Design Model (IHSDM). Federal Highway Administration. Washington, DC. http://www.ihsdm.org

APPENDIX E

PROJECT CASE STUDY: High Friction Surface Treatments, Kentucky Transportation Cabinet.

This appendix shows a summary description of Kentucky's experience with High Friction Surface Treatment; it was prepared by FHWA and can be viewed at www.fhwa.dot/everydaycounts/.

HIGH FRICTION SURFACE TREATMENTS

PROJECT CASE STUDY

The Federal Highway Administration's Every Day Counts (EDC) initiative is designed to identify and deploy innovations aimed at shortening project delivery, enhancing the safety of our roadways and improving environmental sustainability. Building projects more quickly depends on the highway community advancing innovative practices to a level of routine use by highway agencies and contractors. One focus area of the EDC initiative is a pavement overlay option – High Friction Surface Treatments (HFST).

HFST are pavement surfacing systems with exceptional skid-resistant properties that are not typically provided by conventional materials. Through the placement of a thin layer of durable high friction aggregates as a topping on specially engineered resin or polymer binder, these aggregate systems provide long lasting skid resistance, while also making the overlay much more resistant to wear and polishing. In this way, HFST restores pavement friction surfaces where high traffic volumes have polished existing pavement surface aggregates and can also serve to mitigate vehicle speeds that exceed existing geometric designs for sharp curves and superelevations.

Case Study: Kentucky Transportation Cabinet

Roadway departure crashes composed nearly 70 percent of the crashes on Kentucky highway. Because these crashes tend to lead to injury or death, the Kentucky Transportation Cabinet (KTC) decided to treat these problem curves as top priority. For any half-mile roadway section having eight or more wet weather crashes over a 5-year period, the KTC proactively applied HFST using calcined bauxite for the aggregate if the pavement was in good condition.

KNOX COUNTY, KENTUCKY; US 25 SB LANE, AT ITS INTERSECTION WITH X KY 1629 – HFST INSTALLED IN APRIL 2011

The HFST was installed to address rear-end crashes at the intersection. The friction treatment was only applied on US 25 in the southbound lane, which has a downgrade approach. For a 3-year period prior to the installation, there were six wet weather crashes and 27 dry weather crashes (11 crashes/year). The crashes were mostly rear-end crashes. During the 1.3 years after the installation, there were two wet weather crashes and five dry weather crashes (5.38 crashes/year).

OLDHAM COUNTY, KENTUCKY; KY 22, MP4.36 4.44 HFST INSTALLED IN AUGUST 2009 TO TREAT ONE HORIZONTAL CURVE

Prior to the HFST, there were 53 wet weather crashes and three dry weather crashes observed over a 3-year period (18.67 average crashes/year). After the treatment, five wet weather crashes and no dry weather crashes were observed over a period of 3.18 years (1.57 average crashes/year).

For additional information, please contact:

Joseph Cheung, P.E., HFST Lead
FHWA Office of Safety
joseph.cheung@dot.gov

Tracy Lovell, P.E., Transportation Engineer
Kentucky Transportation Cabinet
tracy.lovell@ky.gov

Every Day Counts (EDC), a State-based initiative of FHWA's Center for Accelerating Innovation, works with State, local and private sector partners to encourage the adoption of proven technologies and innovations aimed at shortening and enhancing project delivery.

U.S. Department of Transportation
Federal Highway Administration

APPENDIX F

DESCRIPTIONS OF ROADWAY DEPARTURE PROGRAMS FOR THREE STATES

One of the questions posed in the survey was to ask if a state had implemented one or more countermeasures that were effective in reducing roadway departure crashes. The responses to that question were discussed in Chapter 4. The responses from three states—Alabama, Georgia, and North Carolina—were about their program and believed to be noteworthy to highlight for the synthesis. A summary of a portion of their roadway departure safety improvement program that each state commented on is provided below.

Alabama Department of Transportation

The Alabama DOT is one of the 18 states that had a Roadway Departure Safety Implementation Plan prepared under the sponsorship of FHWA. Under that Plan they undertook a major roadway departure crash identification and evaluation of their state maintained system. They mapped out 430 spot locations on their GIS system, exclusive of their Interstate network. Using two consulting firms, they are conducing roadway safety assessments (audits) at all of these locations. From these site reviews, needed improvements are identified. A full range of improvements (countermeasures) are being considered including enhanced signing, high friction surface treatments, superelevation/cross slope corrections, shoulder improvements (wider shoulder or adding a shoulder on curves, clear zone improvements (tree removal, slope improvements, guardrail improvements), access management, rumble strips, and other countermeasures. Emphasis and priority is given to low-cost improvements (countermeasures) with many being implemented as part of a resurfacing project. Also, if deemed more economical, the projects are being implemented with their DOT crews.

Also, as part of the larger roadway departure program, ALDOT is resigning all sharp curves along their state maintained system, to include removal of existing signing and installation of new signing per the MUTCD, 2009 edition. This involves a team driving the routes utilizing an electronic ball-bank instrument.

Georgia Department of Transportation

The Georgia DOT has a horizontal curve improvement program similar to Alabama. They are driving designated routes using an electronic ball bank indicator to identify “sharp curves.” Figure x shows the “Sharp Curve Treatment Process” that staff are to follow. Once the curves are identified, they develop treatment projects which include the implementation of various roadway departure countermeasures such as highly reflective warning signs and pavement markings, edge line and center line rumble strips, high friction surface treatment, etc.

SHARP CURVE TREATMENT PROCESS
1. Ride the curve in both directions at the posted speed limit and note the reading on the Ball Bank Indicator. 2. Indicator readings registering 12 or more will receive the High Friction Surface Treatment. 3. Curves with readings of 12 or more on the indicator will need to be driven at a lesser speed (5 MPH increments) until the reading on the indicator is less than 12. This speed will be used for the advisory speed for that direction. 4. Any existing advance warning sign should be noted. 5. All existing advisory speed(s) should be noted. 6. All existing chevron(s) should be noted. 7. List and document all existing signs, signs that need to be replaced and any need for additional signs. 8. Document any special/unusual circumstances. NOTE: Employees collecting data should be familiar with the following chapters of the 2009 MUTCD: Chapter 2C. Warning Signs and Object Markers, Chapter 3F. Delineators. After data is collected, coordination with the District Maintenance Office must be done to determine whether opportunities exist to incorporate recommendations into an upcoming maintenance project. Routes with CoPACES ratings below XX will need to be included in said routes' next resurfacing project.

FIGURE 21. Instructions for GADOT staff for conducting site reviews of horizontal curves.

North Carolina Department of Transportation

Lane departure is one of the nine emphasis areas of the North Carolina Strategic Highway Safety Plan, which can be viewed at http://www.ncshsp.org/wp-content/themes/SHSP_Custom/pdfs/SHSP_Complete.pdf. NCDOT notes two of the many challenges to reducing lane departure crashes:

- Determining the best use of resources in areas with countermeasures of widely varied costs and effectiveness.
- Determining the right combination of system-wide countermeasures versus site-specific applications.

To address these two issues, NCDOT has an extensive program of evaluating countermeasures and broadcasting the results to its field offices. It publishes individual project evaluations on the web, including a description of the project location, project background,

summary of improvements, and results and discussion of a “simple” before-after analysis for both total and target crashes. The web-based project evaluation documents allow others within NCDOT to access the evaluation results to inform future decisions and to demonstrate the benefits of past projects when justifying proposed projects to the public. Figure 22 is a screenshot of the website for the NCDOT Safety Evaluation Group. As seen there are two roadway departure countermeasures for which evaluations have or are being conducted—wider edge lines and safety edge.

Safety Evaluation Group

Safety Evaluation Completed Projects

Safety Project Evaluations

In an attempt to assess the safety of our roads, the Safety Evaluation Group of the Traffic Safety Systems Management Section has evaluated the below projects. The methodologies used in these evaluations offer various philosophies and ideas, in an effort to provide objective countermeasure crash reduction results. This information is provided to you so the benefit or lack of benefit for this type of project can be recognized and utilized for future projects. As the Safety Evaluation Group completes additional reviews for these types of countermeasures, we will be able to provide objective and definite information regarding actual crash reduction factors.

Executive Project Summaries

- **Safety Project Evaluations Overview**
- **Roadway Safety Review Program**
- **All Way Stop Evaluation**
- **Roundabout Evaluation**
- **Vehicle Entering When Flashing Evaluation**
- **Flashing Yellow Arrow Evaluation**
- **Pedestrian Countermeasure Evaluations**
- **Signal With and Without Turn Lanes**
- **Dynamic All Red Extension**
- **Wide Edge Lines**
- **Safety Edge**
- **Crash Costs**
- **Unsignalized Synchronized Streets**

FIGURE 22. Screenshot of NCDOT Safety Evaluation website.