Appendix F

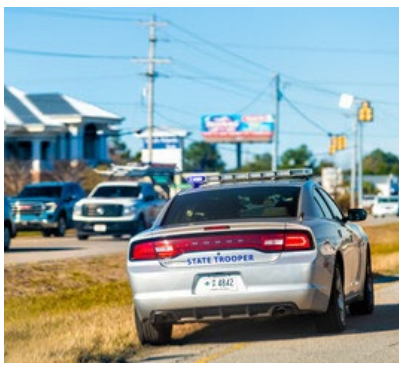
GSATS SAP Countermeasure Toolkit

COUNTERMEASURE TOOLBOX

- EDUCATION / ENFORCEMENT
- POLICY / PARTNERSHIP
- INTERSECTION / CORRIDOR
- SIGNALIZED INTERSECTIONS
- PEDESTRIAN / BICYCLE
- ROADWAY DEPARTURE

EDUCATION / ENFORCEMENT COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Consideration/Application	Safety Benefits	Cost
Speed/Police Enforcement		Police enforcement is an important component to preserving a safe environment for all roadway users.	Enforcement programs are most effective in the form of a well-publicized campaign. Efforts should focus on policing drivers rather than pedestrians Enforcement should be preceded by warnings and media campaigns. Issuing citations and violations are carried out as part of a broader strategic program	Evaluations of high-visibility speed enforcement programs suggest that intense campaigns with publicity can deter speeding on target urban corridors. Reducing the average speed by just 1mph can reduce injury crashes by up to 5%.	$
Motorist and Non-Motorist Education Campaigns/Training		Education initiatives target lack of awareness as well as reckless attitudes towards traffic laws. Messaging encourages individuals to consider their own actions and inspire them to make more informed choices.	Education initiatives are part of a long-term, interdisciplinary approach combined with infrastructure and policy changes. Internal campaigns reinforce the value of safety programs within organizations. Engagement materials should be broadly appealing, with visual and written messages.	While public safety campaigns and training are considered to be an effective tool to improve highway safety, currently there is not a quantified, documented safety benefit available.	$ - $$

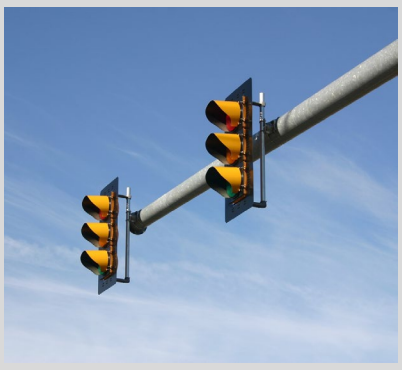
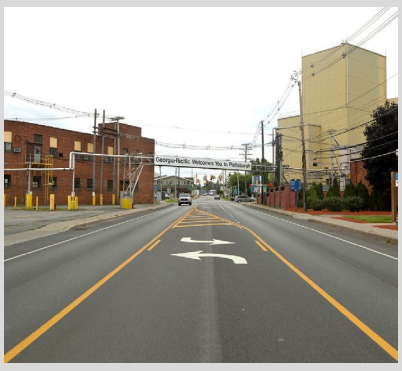
POLICY / PARTNERSHIP COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Consideration/Application	Safety Benefits	Cost
Road Safety Plans		A road safety plan provides a framework for identifying, analyzing, and prioritizing roadway safety improvements. The process results in a prioritized list of issues, risks, actions, and improvements that can be used to reduce fatalities and serious injuries on local roads.	Agencies should consider developing a safety plan to be used as a tool for reducing roadway fatalities, injuries, and crashes. These plans are also a proactive risk management technique to demonstrate an agency's responsiveness, and should be viewed as a living document.	**17-35%** reduction in severe injury and/or fatal crashes according to municipality before/ after studies.	$ - $$
Road Safety Assessments (RSAs)		RSAs are performed by a multidisciplinary team independent of the project. RSAs consider all road users, account for human factors and road user capabilities, are documented in a formal report, and require a formal response from the road owner.	RSAs can be performed in any phase of project development, from planning through construction and can be focused on motorized vehicles, pedestrians, bicyclists, motorcyclists, or a combination of these users. Agencies are encouraged to conduct an RSA at the earliest stage possible.	**10-60%** reduction in crashes	$ - $$
Appropriate Speed Limit Setting		States and local jurisdictions should set appropriate speed limits to reduce the significant risks drivers impose on others—especially vulnerable road users—and on themselves.	When setting a speed limit, agencies should consider a range of factors such as pedestrian and bicyclist activity, crash history, land use context, intersection spacing, driveway density, roadway geometry, roadside conditions, roadway functional classification, traffic volume, and observed speeds.	**Up to 26%** reduction in crashes.	$

INTERSECTION & CORRIDOR COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Application	Safety Benefits	Cost
Add Lighting		Adequate lighting (i.e., at or above minimum acceptable standards) is based on research recommending horizontal and vertical illuminance levels to provide safety benefits to all users of the roadway environment.	Agencies should consider providing lighting based on factors such as a history of crashes at nighttime, traffic volume, the volume of non-motorized users, the presence of crosswalks and raised medians, and the presence of transit stops and boarding volumes.	**33-38%** reduction for nighttime crashes at rural and urban intersections	$$ - $$$
Traffic Signal Installation		Installing a traffic signal at an intersection can improve traffic control and reduce conflicts, particularly at locations where minor road traffic has trouble crossing or merging with high volumes of major road traffic. This intervention can organize vehicle and pedestrian movements, reduce confusion, and enhance safety.	Consider installing traffic signals where history of angle collisions indicates safety concern, high traffic volumes on major road, significant pedestrian activity and comprehensive traffic analysis supports installation based on volume, delay, or crash history.	**Up to 44%** reduction in total crashes **Up to 46%** reduction of angle crashes.	$$
Dedicated Left- and Right-Turn Lanes at Intersections		Auxiliary turn lanes—either for left turns or right turns—provide physical separation between turning traffic that is slowing or stopped and adjacent through traffic at approaches to intersections.	Installing left- and/or right-turn lanes should be considered for the major road approaches for improving safety at both three- and four-leg intersections, where significant turning volumes exist, or with a history of turn-related crashes.	**28-48%** reduction in total crashes (left turn lanes); **14-26%** reduction in total crashes (right turn lane)	$$ - $$$
Corridor Access Management		Access management refers to the design, application, and control of entry and exit points along a roadway. Access can be managed at spot locations or systematically along a corridor through the use of concrete medians, driveway consolidation, and/or additional cross-parcel connectivity.	Consider access management at locations with a history of angle and/or head on crashes, particular those with high access point density and high left-turning traffic volumes.	**25%-31%** reduction in fatal and injury crashes along urban/suburban arterials	$$ - $$$
Improve Pavement Friction		Enhancing pavement friction involves applying treatments to the road surface to increase the resistance between vehicle tires and the pavement. High Friction Surface Treatments (HFST) are a common method which involve applying high-quality aggregates with a polymer binder to significantly boost friction levels.	Agencies should consider improving friction at locations with a history of friction-related crashes, sections where vehicles require greater friction to safely navigate such as on horizontal curves or inclines and at zones with frequent stopping and turning movements or at intersections.	**20%** reduction in total crashes at intersections; **Up to 52%** reduction in wet road condition crashes using HFTS.	$ - $$$
Road Diets (Roadway Reconfiguration)		A Road Diet, or roadway reconfiguration, can improve safety, calm traffic, provide better mobility and access for all road users, and enhance overall quality of life. A Road Diet typically involves converting an existing four-lane undivided roadway to a three-lane roadway consisting of two through lanes and a center two-way left-turn lane (TWLTL).	A Road Diet can be a low-cost safety solution when planned in conjunction with a simple pavement overlay, and the reconfiguration can be accomplished at no additional cost. Typically, a Road Diet is implemented on a roadway with a current and future average daily traffic of 25,000 or less.	4-Lane to 3-Lane Reconfiguration: Up to **50%** reduction in crashes	$$ - $$$
Roundabouts		A circular configuration that safely and efficiently moves traffic. Roundabouts feature channelized, curved approaches that reduce vehicle speed, entry yield control that gives right-of-way to circulating traffic, and counterclockwise flow around a central island that minimizes conflict points.	Roundabouts can be implemented in both urban and rural areas and can replace signals, two-way stop controls, and all-way stop controls. Roundabouts are an effective option for managing speed and transitioning traffic from high-speed to low-speed environments.	**82%** reduction in fatal and injury crashes	$$$
Reduced Left-Turn Conflict Intersections		Reduced left-turn conflict intersections are geometric designs that alter how left-turn movements occur. Examples include the Restricted Crossing U-turn (RCUT) and the Median U-turn (MUT).	Reduced conflict intersections are suitable for and adaptable to a wide variety of circumstances, ranging from isolated rural, high-speed locations to urban and suburban high-volume, multimodal corridors.	**54%** reduction in fatal and injury crashes	$$$

INTERSECTION & CORRIDOR COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Application	Safety Benefits	Cost
Offset Left Turn Lanes		Providing offset of left- and right-turn lanes to increase visibility can provide added safety benefits, and is preferable in many situations, particularly at locations with higher speeds, or where free-flow or permissive movements are possible.	Offset turn lanes should be considered when there are sight distance issues related to left- and/or right-turn lane placement/orientation.	**Up to 36% reduction in fatal and injury crashes**	$$
Turn Lane Extensions		Extending the length of existing left- or right-turn lanes at intersections provides additional storage for decelerating and queuing vehicles, thus reducing the likelihood of rear-end collisions and improving overall traffic flow.	Consider extending turn lanes at intersections with spillover of turning vehicles into through lanes from turn lanes, and at locations with increased rear-end or sideswipe collision relating to inadequate turn lane length.	By providing a dedicated space for turning vehicles to slow down and wait, extended turn lanes minimize the need for sudden lane changes and potential conflicts with oncoming traffic, leading to fewer crashes at intersections.	$ - $$
Sight Distance Improvements		Improving sight distance involves removing physical obstructions, such as vegetation, parked vehicles or roadside structures, that limit driver visibility of oncoming traffic or traffic control devices. Improved sight distance reduces likelihood of collisions.	Agencies should consider sight distance improvements at locations where obstructions hinder visibility of cross traffic or traffic control devices, where road alignment limits sight distance increasing risk of head-on or run-off road crashes, and areas prone to overgrown vegetation or obstructions that can obscure driver's line of sight.	**Up to 56%** reduction in fatal crashes and **up to 37%** reduction in nonfatal crashes	$ - $$

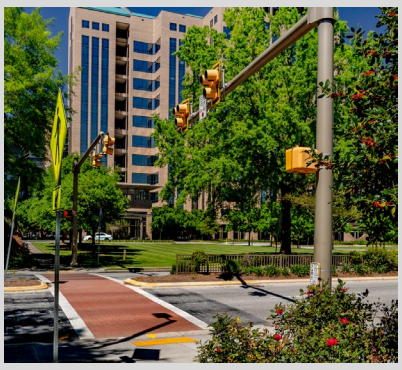
SIGNALIZED INTERSECTION COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Consideration/Application	Safety Benefits	Cost
Improve Signal Phasing/ Hardware and/or Clearance Intervals		Extending yellow and all red time increases the time allotted for the yellow and red lights during a signal phase. Extending yellow and all red time allows drivers and bicyclists a few additional seconds of time at the end of a signal phase to cross through a signalized intersection before conflicting traffic movements are permitted to enter intersection.	Transportation agencies can improve intersection safety at signalized intersections by reviewing and updating their traffic signal timing policies and procedures concerning the yellow change interval. Agencies should institute regular evaluation and adjustment protocols for existing traffic signal timing.	Crash reduction varies based on treatment (e.g. **8-14%** reduction in total crashes for improve yellow change interval)	$
Signal Head Retroreflective Backplates		Backplates added to a traffic signal head improve the visibility of the illuminated face of the signal by introducing a controlled-contrast background, made even more conspicuous by framing it with a 1- to 3-inch yellow retroreflective border.	Transportation agencies should consider backplates with retroreflective borders as part of their efforts to systematically improve safety performance at signalized intersections. Adding a retroreflective border to an existing signal backplate is a very low-cost safety treatment.	Up to 15% reduction in total crashes	$
Flashing Yellow Arrow Signal Heads		Flashing Yellow Arrow (FYA) signal heads are traffic control devices used to indicate permissive left-turn movements at signalized intersections. The FYA informs drivers that they are permitted to turn-left after yielding to oncoming traffic and pedestrians, to reduce confusion associated with traditional circular green indications.	Transportation agencies should consider implementing FYA signal heads at intersections with permissive left-turn phasing on traditional circular green indications, and intersections with history of left-turn collisions.	**Up to 15%** to **25%** reduction of left-turn crashes	$
Signal Retiming		Signal retiming involves adjusting the phases and intervals of traffic signals to optimize the flow of vehicles and pedestrian through intersections. Properly timed signals can reduce delays, decrease fuel consumption, and enhance safety by minimizing aggressive driving behavior such as red-light running.	Transportation agencies should consider implementing signal retiming when there are significant shifts in traffic volumes, when signals have not been retimed in several years, when intersections experience frequent delays and long queues, and/or when intersections have a history of red-light running or rear-end collision.	The retiming of Signals throughout a corridor can reduce crashes by up to 15%	$ - $$

PEDESTRIAN / BICYCLE COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Consideration/Application	Safety Benefits	Cost
Walkways		A walkway is any type of defined space or pathway for use by a person traveling by foot or using a wheelchair. These may be pedestrian walkways, shared use paths, sidewalks, or roadway shoulders.	Transportation agencies should work towards incorporating pedestrian facilities into all roadway projects unless exceptional circumstances exist.	**65-89%** reduction in pedestrian crashes	$$ - $$$
Bicycle Lanes		To make bicycling safer and more comfortable for most types of bicyclists, State and local agencies should consider installing bicycle lanes. Providing bicycle facilities can mitigate or prevent interactions, conflicts, and crashes between bicyclists and motor vehicles, and create a network of safer roadways for bicycling	Bicycle lanes can be included on new roadways or created on existing roads by reallocating space in the right-of-way through road diets. Separated bicycle lanes, which use vertical elements—such as flexible delineator posts, curbs, or vegetation—between the bicycle lane and motorized traffic lanes provide additional safety benefits.	**Up to 49%** reduction in bicycle crashes	$$ - $$$
Crosswalk Enhancements		Crosswalks guide pedestrians to a designated location to cross the street and alert drivers where to expect crossing pedestrians. The ladder pattern of bars is more visible to both drivers and pedestrians than traditional single crosswalk stripes.	High-visibility crosswalks are applicable at all midblock crossings and intersections with high pedestrian activity. Locations should be convenient for pedestrian access.	**Up to 42%** reduction in pedestrian crashes	$
Pedestrian Hybrid Beacons (PHB)		Pedestrian hybrid beacons (PHBs) are a user activated traffic control device that assists pedestrians crossing the street at an unsignalized crossing. They remain “dark” or blank until a pedestrian wishes to cross. A sequence of lights directs motorists to slow and come to a stop allowing the pedestrian to safely cross.	PHBs are typically used for midblock crossings or unsignalized intersections with three or more lanes. They are best applied where vehicle speeds exceed 35-40MPH and volumes are over 9,000 AADT.	**Up to 55%** reduction in pedestrian crashes	$$
Rectangular Rapid Flashing Beacons (RRFB)		RRFBs alert vehicles of a crossing pedestrian. They include a pedestrian, school, or trail crossing sign combined with user activated flashing light. The lights increase visibility at crossings and lead to high vehicle yield rates.	Best for high volume mid-block crossings with low-to-moderate vehicle speeds (<40MPH). RRFBs should be placed at both sides of a crosswalk. If a median is present, RRFBs should be placed in the median rather than on the far side of the roadway.	**Up to 47%** reduction in pedestrian crashes	$ - $$
Leading Pedestrian Intervals (LPIs)		Leading Pedestrian Intervals (LPIs) allow pedestrians to fully enter a crosswalk before vehicles are given the green light to turn, giving priority to pedestrians over vehicles making right or left-hand turns. LPIs reduce conflicts between pedestrians and vehicles and increase the visibility of pedestrians.	LPIs are most effective when paired with right-turn on red restrictions. Intersections with very high pedestrian traffic may also consider an exclusive pedestrian interval.	**13%** reduction in pedestrian crashes at intersections	$
Medians, Pedestrian Refuge Islands, and/or Curb Extensions		A median is the area between opposing lanes of traffic, excluding turn lanes. Medians in urban and suburban areas can be defined by pavement markings, raised medians, or islands to separate motorized and non-motorized road users. A pedestrian refuge island is a median with a refuge area that is intended to help protect crossing pedestrians.	Transportation agencies should consider medians or pedestrian refuge islands in curbed sections of urban and suburban multilane roadways, particularly in areas with a significant mix of pedestrian and vehicle traffic, traffic volumes over 9,000 vehicles per day, and travel speeds 35 mph or greater.	**Up to 56%** reduction in pedestrian crashes.	$-$$
Add Lighting		Traditional roadway lighting is typically focused on the needs of vehicles. Disproportionate number of fatal and serious injury pedestrian and bicycle crashes occur at night. Lighting makes pedestrians more visible to vehicles and can also improve pedestrians’ personal security.	At crossings, lighting should be installed on both sides of the street. Lighting placement should be forward of the crossing to avoid silhouetting the pedestrian.	**42%** reduction for nighttime injury pedestrian crashes at intersections	$ - $$

PEDESTRIAN / BICYCLE COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Consideration/Application	Safety Benefits	Cost
Enhanced Signing and Marking		These countermeasures include yield/stop here for pedestrian signs, in-street pedestrian crossing signs, and advance yield/stop pavement markings. Signage and pavement markings make crossings and pedestrians in crossings more visible. Signs also remind and reinforce stopping and yielding right of way requirements for drivers.	In-street signs should be placed between travel lanes or in a median. Too much signage can lead to clutter and lack of overall emphasis. Drivers may also ignore signage if it is placed too close or too far in advance of the crosswalk.	Advance yield or stop markings and signs can reduce pedestrian crashes up to 25%	$
Pedestrian Countdown Signals		Pedestrian countdown signals consist of a standard "walk/don't walk" signal combined with a display showing the amount of time remaining to cross. Countdown signals help pedestrians judge whether there is sufficient time to cross which may be especially helpful for children or older adults who take longer to cross.	Countdown signals are required by MUTCD to be installed whenever pedestrian signals are added or updated.	The installation of pedestrian countdown timers can reduce total crashes by up to 5%.	$
Right-Turn Restrictions		Right-turn restrictions typically involve prohibiting right-turn on red. This reduces conflicts between pedestrians (who would typically have the right of way during the red for the right-turning movement in question) crossing the crosswalk in downstream of the right-turning movement.	In locations with heavy pedestrian traffic which often conflicts with right-turning vehicles.	Prohibiting right turns on red is a simple, low-cost measure. Together with a leading pedestrian interval, the signal changes can benefit pedestrian safety with minimal impacts on traffic.	$

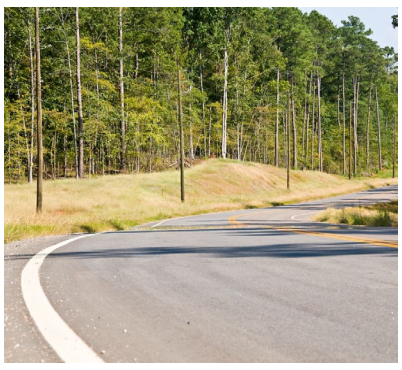
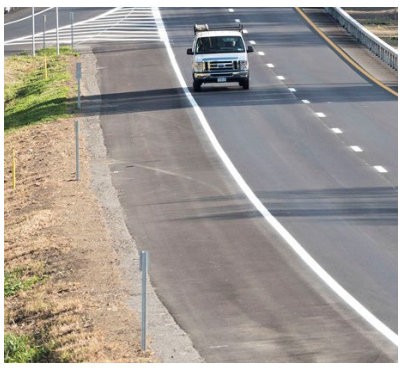
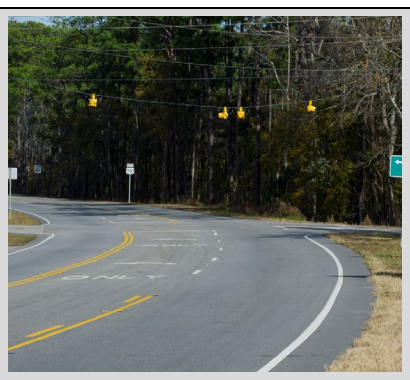
ROADWAY DEPARTURE COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Consideration/Application	Safety Benefits	Cost
Rumble Strips/Stripes		Rumble strips are milled or raised elements on the pavement intended to alert drivers through vibration and sound that their vehicle has left the travel lane. They can be installed on the shoulder, edge line, or at or near the center line of an undivided roadway. Rumble stripes are rumble strips where the pavement marking is placed over the rumble strip.	Transportation agencies should consider milled center line rumble strips (including in passing zone areas) and milled edge line or shoulder rumble strips with bicycle gaps for systemic safety projects, location-specific corridor safety improvements, as well as reconstruction or resurfacing projects.	**Up to 51%** reduction in fatal and serious injury road departure-related crashes on 2-lane rural roads	$
Median Barriers		Median barriers are longitudinal barriers that separate opposing traffic on a divided highway and are designed to redirect vehicles striking either side of the barrier.	To reduce cross-median crashes, transportation agencies should review their head-on crash history on divided highways to identify hot spots. Agencies should also consider implementing a systemic approach to median barrier placement based on cross-median crash risk factors.	**97%** reduction in cross-median crashes	$$ - $$$
Roadside Barriers		Guardrails redirects a vehicle away from embankment slopes or fixed objects. It is installed to reduce the severity of road departure crashes. However, it should only be used in conditions where striking the barrier is less severe than going down the embankment or striking a fixed object.	Consider application of guardrails on roadway segments with curves and/or high number of roadway departure collisions	Studies have shown that installing roadside barriers can significantly reduce the severity of run-off-road crashes, especially when placed strategically near hazardous roadside features.	$$ - $$$
Removal or Relocation of Obstacles/Fixed Objects		The clear zone, or an unobstructed, traversable area beyond the edge of the traveled way, is an important safety feature of a roadway to allow for the recovery of errant vehicles.	By providing adequate Clear Zones on all roadways, agencies can increase the likelihood that a roadway departure results in a safe recovery rather than a crash and mitigate the severity of crashes that do occur. Clear zone width is based on risk (also called exposure). Key factors in assessing risk include traffic volumes, speeds, and slopes.	Improving clear zone areas by removing or relocating fixed objects can reduce those type crashes by more than 90%..	$ - $$$

ROADWAY Ddeparture COUNTERMEASURES

$ - low (<$100k)
$$ - Medium ($100k - $1m)
$$$ - high (>$1m)

Countermeasure		Description	Consideration/Application	Safety Benefits	Cost
Wider Edge Lines		Wider edge lines enhance the visibility of travel lane boundaries compared to traditional edge lines. Edge lines are considered "wider" when the marking width is increased from the minimum normal line width of 4 inches to the maximum normal line width of 6 inches.	Wider edge lines are most effective in reducing crashes on rural two-lane highways, especially for single-vehicle crashes. Agencies should also consider implementing a systemic approach to wider edge line installation based roadway departure crash risk factors, including pavement and shoulder widths, curves, traffic volumes, and nighttime crashes.	**37%** reduction in road departure-related crashes (fatal and injury crashes on rural, two-lane roads)	$ - $$
Improve Pavement Friction (in Horizontal Curves)		Enhancing pavement friction involves applying treatments to the road surface to increase the resistance between vehicle tires and the pavement. High Friction Surface Treatments (HFST) are a common method which involve applying high-quality aggregates with a polymer binder to significantly boost friction levels.	Agencies should consider improving friction at locations with a history of friction-related crashes, sections where vehicles require greater friction to safely navigate such as on horizontal curves or inclines and at zones with frequent stopping and turning movements or at intersections.	**48%** reduction in injury crashes at horizontal curves	$ - $$
Wider Shoulders and/or "SafetyEdge℠"		Exposed vertical pavement edges can cause vehicles to become unstable and prevent their safe return to the roadway. Wider shoulders/"SafetyEdge℠" gives drivers the opportunity to return to the travel lane while maintaining vehicle control.	Transportation agencies should develop standards for implementing the SafetyEdge℠ systemwide on all new asphalt paving and resurfacing projects where curbs and/or guardrail are not present, while also encouraging standard application for concrete pavements.	**11%** reduction in fatal and injury crashes; **21%** reduction in run-off road crashes; **19%** reduction in head-on crashes	$ - $$
Roadside Design Improvements at Curves		Roadside design improvements at curves is a strategy encompassing several treatments that target the high-risk roadside environment along the outside of horizontal curves. These treatments can reduce roadway departure fatalities and serious injuries by giving vehicles the opportunity to recover safely and by reducing crash severity.	In cases where a vehicle leaves the roadway, having strategic roadside design elements, including an added or widened shoulder, flattened sideslopes, or a widened clear zone can provide drivers with an opportunity to regain control and re-enter the roadway in their lane or come to a safe stop before rolling over or encountering a fixed object.	**8% - 44%** reduction in single-vehicle crashes	$ - $$$
Enhance Delineation for Horizontal Curves		Enhanced delineation at horizontal curves includes a variety of potential strategies that can be implemented in advance of or within curves, in combination, or individually. Enhanced delineation treatments can alert drivers to upcoming curves, the direction and sharpness of the curve, and appropriate operating speed.	Agencies can review signing practices and policies to ensure they comply with the Manual on Uniform Traffic Control Devices (MUTCD) principles of traffic control devices. Consistent practice for similar curves sets the appropriate driver expectancy. Use the systemic approach to identify and treat problem curves.	Chevron signs can have **16%** reduction in non-intersection fatal and injury crashes and **25%** reduction in night-time crashes.	$