ATTACHMENT A

Objectives and Strategies Table

THIS PAGE INTENTIONALLY LEFT BLANK.

EXHIBIT A-1

Objectives and Strategies for Local Agencies

Note: An "X" represents the most common or most appropriate locations for use of the listed strategies. However, the absence of an "X" does not indicate that the strategy can not be used for that particular roadway classification

	Rural			Urban		
	Arterial	***Collector***	***Local***	***Arterial***	***Collector***	***Local***
Objective I. Reduce Intersection Crashes						
1) **Provide left-turn or right-turn lanes and enhancements**	X	X		X	X	
2) Provide right-turn acceleration lanes	X	X		X	X	
3) Provide bypass lanes at T-intersections	X	X		X	X	
4) Improve intersection sight distance	X	X	X	X	X	X
5) Improve visibility of intersections with signing and delineation	X	X		X	X	
6) Improve visibility of intersection with pavement markings	X	X	X	X	X	X
7) Improve nighttime visibility with lighting	X	X		X	X	X
8) install transverse rumble strips on intersection approaches	X	X				
9) Select improved geometric and traffic control type and design	X	X	X	X	X	X
10) Improve signal timing and driver awareness of signals	X			X	X	
11) Improve access management	X	X		X	X	
12) Convert 4-lane undivided roadways to 3-lane roadways ("road diet")				X	X	
13) Reduce or eliminate intersection skew	X	X		X	X	
14) Red-light enforcement program	X	X		X	X	

EXHIBIT A-1

Objectives and Strategies for Local Agencies

Note: An "X" represents the most common or most appropriate locations for use of the listed strategies. However, the absence of an "X" does not indicate that the strategy can not be used for that particular roadway classification

	Rural			Urban		
	Arterial	***Collector***	***Local***	***Arterial***	***Collector***	***Local***
Objective II. Keep Vehicles on the Roadway						
1) Improve advanced curve warning and curve delineation	**X**	**X**	**X**	**X**	**X**	**X**
2) Improve pavement markings and delineation	**X**	**X**	**X**	**X**	**X**	**X**
3) Install shoulder rumble strips, edgeline rumble strips	**X**	**X**	**X**			
4) Minimize or eliminate pavement edge drop offs	**X**	**X**				
5) Use alternating passing lanes or 4-lane sections	**X**	**X**				
6) Include a narrow "buffer median"	**X**	**X**			**X**	
Objective III. Reduce Lane Departure Crashes						
1) Remove or relocate fixed objects	**X**	**X**	**X**	**X**	**X**	**X**
2) Shield drivers from roadside fixed objects	**X**	**X**	**X**	**X**	**X**	**X**
3) Develop, revise, and implement guidelines	**X**	**X**	**X**	**X**	**X**	**X**
4) Design safer slopes and ditches to prevent rollovers	**X**	**X**	**X**			

EXHIBIT A-1

Objectives and Strategies for Local Agencies

Note: An "X" represents the most common or most appropriate locations for use of the listed strategies. However, the absence of an "X" does not indicate that the strategy can not be used for that particular roadway classification

	Rural			Urban		
	Arterial	***Collector***	***Local***	***Arterial***	***Collector***	***Local***
Objective IV. Reduce Pedestrian and Bicyclist Crashes						
1) Provide sidewalks/walkways and curb ramps	**X**	**X**		**X**	**X**	**X**
2) Provide bike lanes and bike paths	**X**	**X**		**X**	**X**	**X**
3) Provide lighting and paved shoulders	**X**	**X**		**X**	**X**	**X**
4) Provide traffic calming measures (A & B)					**X**	**X**
5) Install or upgrade traffic and pedestrian signals				**X**	**X**	
6) Improve intersection geometry	**X**	**X**		**X**	**X**	**X**
Objective V. Improve Enforcement and Education Programs						
1)Implement aggressive driving programs	**X**	**X**	**X**	**X**	**X**	**X**
2) Better manage vehicle speeds	**X**	**X**	**X**	**X**	**X**	**X**
3) Encourage seat (safety) belt use	**X**	**X**	**X**	**X**	**X**	**X**
4) Reduce driving under the influence	**X**	**X**	**X**	**X**	**X**	**X**
Objective VI. Improve Emergency Medical Services						
1)Prepare personnel to provide first aid on roadways	**X**	**X**	**X**	**X**	**X**	**X**
2) Reduce emergency medical services response time to a crash	**X**	**X**	**X**			
3) Educate road workers to manage incidents	**X**	**X**	**X**	**X**	**X**	**X**

EXHIBIT A-1

Objectives and Strategies for Local Agencies

Note: An "X" represents the most common or most appropriate locations for use of the listed strategies. However, the absence of an "X" does not indicate that the strategy can not be used for that particular roadway classification

	Rural			Urban		
	Arterial	***Collector***	***Local***	***Arterial***	***Collector***	***Local***
Objective VII. Innovative Safety Techniques (these are newer and emerging strategies that are not yet proven or tried)						
T1) Targeted education of high crash locations	**X**	**X**	**X**	**X**	**X**	**X**
T2) Local 4E crash debriefings	**X**	**X**	**X**	**X**	**X**	**X**
T3) Educate maintenance workers to improve safety	**X**	**X**	**X**	**X**	**X**	**X**
T4) Provide bus stop locations with accessible sidewalks, crosswalks	**X**	**X**	**X**	**X**	**X**	**X**
T5) Implement quick law enforcement crash data reporting	**X**	**X**	**X**	**X**	**X**	**X**

ATTACHMENT B

Safety Strategy Summaries

THIS PAGE INTENTIONALLY LEFT BLANK.

I.1) Provide Left-Turn or Right-Turn Lanes and Enhancements (P,T)

Strategy Overview

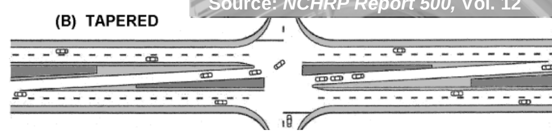
Provide turn lanes at intersections with a pattern of turning maneuver crashes or at locations with current or future high turning volumes.

Enhancements

- Lengthen existing turn lanes to increase storage and deceleration length.
- Use offset left-turn lanes for left-turning drivers to improve ability to see approaching traffic when another vehicle is stopped in the opposing left-turn lane. Offset right-turn lanes give drivers stopped on the cross-street a better view of approaching traffic by moving slowing/turning vehicles further from the through lanes.

Strategy applies at signalized or unsignalized intersections in both rural and urban settings.


Source: *NCHRP Report 500,* Vol. 12



Source: AASHTO, *A Policy on Geometric Design of Highways and Street*

Targeted Crashes – Patterns

- Intersection crashes involving a turning vehicle, including rear-end crashes where one vehicle is slowing/stopped to turn.
- Crashes involving a left-turning vehicle and an oncoming vehicle.
- Crossing path crashes where a right-turning vehicle obstructs the view of a vehicle stopped on the cross-street.

Recommended Areas for Application

Rural
- ☒ Arterial
- ☒ Collector
- ☐ Local

Urban
- ☒ Arterial
- ☒ Collector
- ☐ Local

Implementation Time & Issues, Costs, and Associated Needs

Three to six months; assumes no new right-of-way is required.

Cost will be highly dependent on the existing roadway geometry and intersection traffic control (stop controlled or traffic signal). A few thousand dollars may be needed for roads that simply need to be re-striped or where paved shoulders can be used for right-turn lanes.

Agencies may need to educate adjacent landowners on the safety benefits of turn lanes, especially if changes in access management are needed in order to accommodate the improvements.

Effectiveness*

Crash modification factors (CMFs) for installation of turn lanes on major road approaches (all crashes):

Turn Type	Area	Intersection		CMF Approaches	
		Type	Control	One	Two
Left	Rural	3 Leg	STOP	0.56	N/A
Left	Rural	3 Leg	Signal	0.85	N/A
Left	Rural	4 Leg	STOP	0.72	0.52
Left	Rural	4 Leg	Signal	0.82	0.67
Left	Urban	3 Leg	STOP	0.67	N/A
Left	Urban	3 Leg	Signal	0.93	N/A
Left	Urban	4 Leg	STOP	0.73	0.53
Left	Urban	4 Leg	Signal	0.90	0.81
Right	Both	Any	STOP	0.86	0.74
Right	Both	Any	Signal	0.96	0.92

* More information and references are available in the related strategies in the *NCHRP Report 500* series.
N/A = Not available

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategies 17.1 B1, B2, B3, B6, B7, B8
NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategies 17.2 B1, B2

I.2) Provide Right-Turn Acceleration Lanes (T)

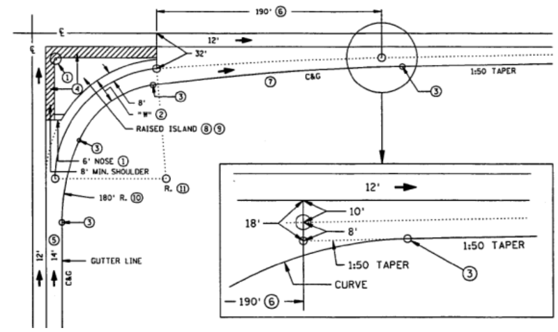
Strategy Overview

Provide a right-turn acceleration lane at intersections where the crash problem is related to right-turn maneuvers or high mainline volumes make it difficult for entering traffic to find gaps.

Enhancements

- Allow vehicles to reach prevailing travel speeds before merging into the travel lanes with the cross-traffic.
- Provide sufficient length, tapers, and radii to allow turning and through vehicles to adjust speeds in order to accommodate a safe merge.

This strategy applies at signalized or unsignalized intersections in both rural and urban settings. However, this strategy is typically reserved for a high-speed and/or high-volume through street (that is, cross-street).



Example Urban Design of a Right-Turn Acceleration Lane
(Source: Minnesota DOT Design Manual, Figure 5-2.04B)

Target Crashes – Patterns

Intersection collisions involving one vehicle turning right and a through vehicle approaching the right-turning vehicle from the left. Typically a sideswipe or rear-end crash, but could also be considered an angle (that is, broadside) crash.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☐ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

Could take as little as a few months when a paved shoulder can be converted into an acceleration lane or up to three or four years for new construction. Generally the biggest factor affecting implementation time is construction related to roadway widening.

Cost will be highly dependent on the existing roadway width and intersection traffic control (stop controlled or traffic signal). A few thousand dollars may be needed for roads that simply need to be re-striped or where paved shoulders can safely be used for the acceleration lane.

Agencies may need to educate adjacent landowners on the safety benefits of turn lanes, especially if changes in access management are needed.

Effectiveness*

It was reported that right-turn acceleration lanes operate effectively and do not create safety issues if properly implemented. However, a quantified estimate of the safety effectiveness of right-turn acceleration lanes at intersections is not known, with more research needed.

* More information and references are available in the related strategy in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy

For more information and references, refer to the following strategy in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategy 17.1 B9

I.3) Provide Bypass Lanes at T-Intersections (T)

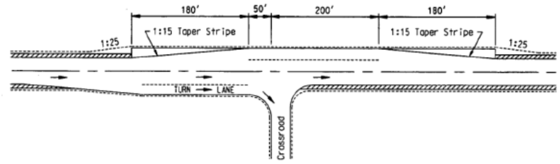
Strategy Overview

A bypass lane can be used at a 2-lane rural or urban T-intersection.

Enhancements

- Provide an auxiliary lane to create an abbreviated left-turn lane. The bypass lane is added to the "top" of the T-intersection, which allows vehicles on the major road to bypass vehicles stopped and waiting to turn left onto the minor road.
- Convert full-width paved shoulders into a bypass lane to save on cost. However, use of paved shoulders should be carefully considered before using at high-volume or high-speed intersections.

Often bypass lanes can be constructed at a lower cost than a left-turn lane, especially at low volume locations or along roads with low travel speeds. However, bypass lanes are not recommended for signalized intersections or at intersections with four or more approaches.



Example Bypass Lane at a T-Intersection
(Source: Minnesota DOT Design Manual, Figure 5-4.01A)

Targeted Crashes – Patterns

Two types of intersection crashes involving vehicles on the major road:

1. Rear-end crash with one vehicle turning left onto the minor road and the other vehicle continuing straight.
2. Left-turn crash with an oncoming vehicle, where the driver turning left may have felt "rushed" by a waiting vehicle behind.

Recommended Areas for Application

Rural
- ☒ Arterial
- ☒ Collector
- ☐ Local

Urban
- ☒ Arterial
- ☒ Collector
- ☐ Local

Implementation Time & Issues, Costs, and Associated Needs

At locations with a full-width paved shoulder, a bypass lane could be added in a few months by simply changing the signing and markings. At locations where reconstruction is need, the implementation time could take several years.

Implementation at a location with an existing paved shoulder may require only a few thousand dollars for materials and labor.

Typically, drivers readily understand how to use a bypass lane at a T-intersection. Therefore, no public education and information campaigns should be required.

Effectiveness*

Previous studies of this strategy have not led to a consensus on their effectiveness and more study is recommended. In a Minnesota study, bypass lanes did not increase safety when compared to intersections with left-turn lanes or intersections with no turn lanes. In contrast, a "marked decrease in rear-end collisions" was reported at Nebraska intersections where shoulder bypass lanes were added.

If properly designed considering traffic volumes and travel speeds, adding bypass lanes at a T-intersection should operate safely.

* More information and references are available in the related strategy in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy

For more information and references, refer to the following strategy in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategy 17.1 B4

I.4) Improve Intersection Sight Distance (P,T)

Strategy Overview

Improve intersection sight distance by removing obstructions in the intersection sight triangles (including in the median) or redesign the horizontal/ vertical alignment to provide better sight distance (such as eliminate skew or flatten a crest vertical curve).

Enhancements

- Provide a clear area is to allow drivers on the side street when selecting a gap in traffic to see if any vehicle is approaching.
- Provide drivers approaching an intersection on the major road with a clear sight triangle that allows them to better see if vehicles on the minor road are slowing down to stop.

Intersection sight distance is an issue for both urban and rural intersections. While providing appropriate intersection sight distance is desirable for all intersections, it is especially important for unsignalized intersections since drivers are responsible for selecting a gap in the cross-traffic.

Targeted Crashes – Patterns

Intersection crashes involving a vehicle approaching from the major and minor road, namely angle crashes including those involving turning vehicles.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

Clearing most sight triangles can be accomplished in a matter of weeks or months, especially if the obstruction is in the right of way. Obstructions from “permanent” objects (such as utility poles) or private property may require more time and resources before they can be removed. Projects involving a change to the vertical or horizontal alignment may require several years to be implemented.

The costs of removing most objects in sight triangles is typically low. Changing the alignment will often have a high cost.

Agencies may need to educate land owners on the benefits of keeping intersection sight triangles free of obstructions. Agencies may also need to pursue legislation or ordinances that allow for removing objects on private property that may limit visibility.

Effectiveness*

At unsignalized intersections, improving the intersection sight distance may reduce related crashes by as much as 20% -- depending on the number of quadrants affected and the actual sight distance available.

Findings are based on the estimate from a panel of traffic safety experts. In their findings, if the available sight distance at an intersection quadrant is only sufficient for a design speed less than or equal to the actual 85th-percentile speed minus 12.5 mph (20 kph), then the frequency of related crashes — involving the deficient quadrant — at the intersection would be increased by 5% compared to the provision of sufficient sight distance for a given speed.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategies 17.1 C1, C2, C3, C4

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategies 17.2 C1, C2, G5

I.5) Improve Intersection Visibility with Signing and Delineation (T)

Strategy Overview

Alerts drivers when they are approaching an intersection through enhanced delineation and signing.

Enhancements

- Larger regulatory and warning signs
- Larger guide signs placed more in advance of the intersection
- Activated flashing beacons
- Multiple signs mounted on the left and right side of the road or overhead
- Signs with high-grade retroreflective sheeting material.

Can also be used to notify drivers on the uncontrolled approaches to make them more aware of potential conflicts from entering traffic.

This strategy is appropriate at rural and urban settings and for a variety of intersection traffic control scenarios; including signalized, all-way stop, two-way stop, uncontrolled, and roundabouts.

Targeted Crashes – Patterns

Intersection crashes where a driver may be unaware of their approach to an intersection, resulting in:

- A rear-end crash
- An angle crash
- A turn related crash

The crash report narrative may indicate the driver on the major road did not expect a vehicle to turn across or into their lane.

Recommended Areas for Application

Rural

- ☒ Arterial
- ☒ Collector
- ☐ Local

Urban

- ☒ Arterial
- ☒ Collector
- ☐ Local

Implementation Time & Issues, Costs, and Associated Needs

Implementation time at a single intersection is expected to be short -- possibly a few months — and the cost for a single intersection could be low. One issue that may increase the implementation time and cost includes providing electric power to operate flashing beacons. Also, deployment at numerous intersections, such as along a corridor, could increase the implementation time and costs.

Agencies should consider developing best practices and recommended guidance that designers and maintenance staff can follow during new construction or routine maintenance.

Associated with enhancing or adding signage is the potential for sign clutter or excessive use, which may decrease effectiveness. Before adding signs, the five basic requirements listed in the MUTCD should be reviewed (MUTCD, Section 1A.02).

Effectiveness*

To date, no research studies have been able to adequately quantify the expected safety effectiveness of this strategy. At this time, estimates of crash reductions are best determined given the site conditions, including identifying the number of crashes where at least one driver was unaware of the intersection — this would also include a crash where the driver on the major road was not aware vehicles may be crossing or turning into their path. To identify the crashes where a driver's failure to recognize the intersection was a contributing factor, the narrative in the officer reports would likely contain this information.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategies 17.1 E1, E5, E8, E11
NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategy 17.2 D1

I.6) Improve Intersection Visibility with Pavement Markings (T)

Strategy Overview

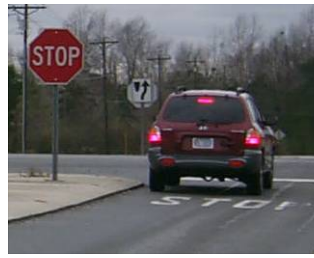
Alert drivers when they are approaching an intersection by using enhanced pavement markings and pavement marking word messages.

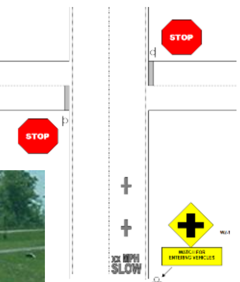
Enhancements

- Add a stop bar (or wider stop bar); STOP AHEAD, SIGNAL AHEAD, or other messages on the pavement.
- Add warning messages on the major road.

Can also be used for drivers on the uncontrolled approaches to increase awareness of potential conflicts from entering traffic.

This strategy is appropriate at rural and urban settings and for a variety of intersection traffic control scenarios; including signalized, all-way stop, two-way stop, uncontrolled, and roundabouts.





Courtesy of Pennsylvania DOT

Targeted Crashes – Patterns

- Intersection crashes where a driver may be unaware of their approach to an intersection, resulting in a rear-end crash
- An angle crash
- A turn-related crash

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

Implementation time at a single intersection is expected to be short and the cost for a single intersection could be low. One issue that may increase the implementation time and cost is deployment at numerous intersections, such as along a corridor.

Agencies should consider developing best practices and recommended guidance that designers and maintenance staff can follow during new construction or routine maintenance.

Associated with enhancing pavement markings is the potential for excessive use, which may decrease effectiveness. Before adding pavement markings, the five basic requirements for a traffic control device listed in the MUTCD should be reviewed (MUTCD, Section 1A.02). Also, pavement markings require routine maintenance to be visible, especially after snow plowing.

Effectiveness*

At this time, estimates of crash reductions are best determined given the site conditions, including the number of crashes where at least one driver was unaware of the intersection — this would also include a crash where the driver on the major road was not aware vehicles may be crossing or turning into their path. To identify the crashes where a driver's inability to recognize the intersection was a contributing factor, the narrative in the crash reports may contain this information.

A recent FHWA study (Gross et. al., 2007) found that STOPAHEAD pavement markings were associated with a 31% reduction in crashes at 17 sites studied in Arkansas and Maryland. The authors' conservative estimate was that STOP AHEAD pavement markings could provide a 15% reduction in intersection crashes.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies and Other Resources

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategies 17.1 E4, E9

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategy 17.2 D1

Gross, F., R. Jagannathan, B. Persaud, C. Lyon, K. Eccles, N. Lefler, and R. Amjadi. *Safety Evaluation of STOP AHEAD Pavement markings*. FHWA-HRT-08-043. Federal Highway Administration, Washington, D.C., December 2007.

I.7) Improve Intersection Visibility at Night with Street Lighting (P)

Strategy Overview

Improve driver's visibility of the intersection at night by adding appropriate street lighting. Lighting is also used to improve visibility of pedestrians, bicyclists, and animals; helping drivers to avoid a collision.

Enhancements

- A single light at the intersection — destination lighting
- Lighting two or more quadrants along with the intersection approaches.

This strategy may benefit law enforcement and emergency responders that are out of their vehicle during a traffic stop or when at the scene of a crash.

This strategy applies to both rural and urban locations. It can also be used with a variety of intersection traffic control situations, including signalized, unsignalized, and roundabout.

Targeted Crashes – Patterns

- Nighttime intersection crashes, including rear end, angle, and road departure.
- Collisions with pedestrian, bicycle, or animal.
- Crashes involving officers or emergency responders on the road.

Recommended Areas for Application

Rural		Urban	
☒	Arterial	☒	Arterial
☒	Collector	☒	Collector
☐	Local	☒	Local

Implementation Time & Issues, Costs, and Associated Needs

The design and implementation of a lighting project may require up to a year. The installation of a single light may be as little as $1,000 plus the ongoing maintenance and power costs if the street light is installed on an existing power pole as illustrated in the above photo in the lower left. The cost of intersection lighting projects may increase significantly if power is not readily available or multiple lights are installed.

Agencies should review policies related to adding intersection lighting as a safety countermeasure, ensuring that policies are not too restrictive on their use.

Effectiveness*

Past studies indicate that installing streetlights at rural intersections result in a 25% to 50% reduction in the nighttime crash/total crash ratio. Since the release of *NCHRP Report 500*, Volume 5, several additional studies have been completed. The first, an update of a Minnesota study, found in a before-after analysis that there was a 27% reduction in the frequency of nighttime collisions after installing lighting (Isebrands et. al., 2004). The same study also found a 35% reduction in nighttime crash rates. The severity of crashes at these rural intersections decreased by 20%.

The Kentucky Transportation Center also conducted a recent study of the safety effectiveness of lighting. The study found that nighttime crashes dropped approximately 45% after lights were installed at intersections (Green et. al., 2003).

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies and Other Resources

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategy 17.1 E2

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategy 17.2 D1

Isebrands, H., S. Hallmark, Z. Hans, T. McDonald, H. Preston, and R. Storm. *Safety Impacts of Street Lighting at Isolated Rural Intersections - Part II, Year 1 Report*. Center for Transportation Research and Education, Iowa State University. December 2004.

Green, E., K. Agent, M. Barrett, and J. Pigman. *Roadway Lighting and Driver Safety*. Kentucky Transportation Center, University of Kentucky. May 2003.

I.8) Install Transverse Rumble Strips on Intersection Approaches (T)

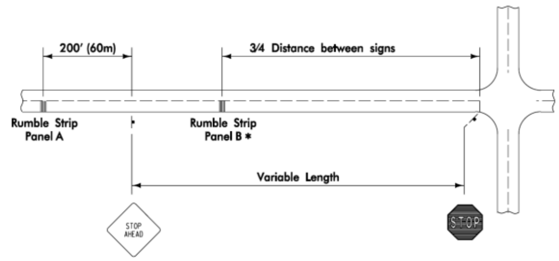
Strategy Overview

Used on the approach to an intersection, this strategy is intended to draw a driver's attention to the traffic control ahead through the generation of noise and vibration.

Enhancements

- A supplement to other traffic control devices.
- Position the rumble strips so that a STOP AHEAD sign is in view when a driver crosses over them.

This strategy is typically used at unsignalized intersections on stop-controlled approaches. Consideration should be given to other alternatives before using transverse rumble strips for signalized intersections and at through approaches at unsignalized intersections. Because of the noise created, this strategy may not be appropriate in urban or developed areas; therefore, rural intersections are the primary choice.



Example Rumble Strip Application
(Source: Iowa DOT Design Manual, 6A-7)

Targeted Crashes – Patterns

Intersection crashes where drivers are unaware of their approach to an intersection, resulting in:

- Rear-end crash.
- Angle crash (that is, running a STOP sign).

This strategy will not be effective in reducing right angle crashes where a driver stopped and then pulled in front of a vehicle.

Recommended Areas for Application

Rural
- [x] Arterial
- [x] Collector
- [ ] Local

Urban
- [ ] Arterial
- [ ] Collector
- [ ] Local

Implementation Time & Issues, Costs, and Associated Needs

Implementation time and cost will be nominal for most intersections, but the strategy should be tried after unsuccessful attempts to increase driver awareness with enhanced signing, delineation, and pavement markings.

Over time, transverse rumble strips will begin to wear down from the repetition of vehicles driving across them. This requires periodic maintenance to ensure the rumble strips continue to produce sufficient noise and vibration to alert drivers.

Other reported difficulties associated with implementation of transverse rumble strips include potential loss-of-control issues for motorcyclists and bicyclists; difficulties created for snowplow operations; and inappropriate driver responses such as using the opposing travel lanes to drive around the rumble strip.

Effectiveness*

Transverse rumble strips are intended to address a driver's unawareness of an approaching intersection and traffic control. There is no consensus on their effectiveness. However, some suggest that rumble strips on intersection approaches can provide a reduction of at least 50% of the crash types targeted.

To accurately identify the number of correctable crashes — where a driver failed to recognize the intersection — the narrative in the officer reports will most likely have to be reviewed.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategy 17.1 E6

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategy 17.2 D1

I.9) Select Improved Geometric and Traffic Control Design (P,T)

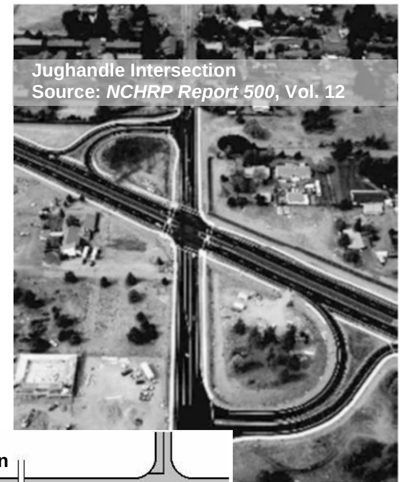
Strategy Overview

To consider improved intersection traffic control and appropriate geometric design for an intersection.

Enhancements

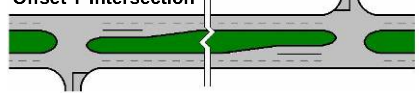
- Create offset T-intersections from a four-legged intersection; eliminate offset T-intersections that have insufficient separation between intersections; create one-quadrant intersections; create jug handle intersections; or splitter islands on minor road approaches.
- Intersection traffic control options include roundabouts, all-way stop control, removing unwarranted signals, and continuous flow intersection.

Before implementing any of these options, more information on best practices should be gathered from the *AASHTO Policy on Geometric Design*, MUTCD, *Highway Capacity Manual*, state design manuals, *NCHRP Reports* and other references.



Jughandle Intersection
Source: *NCHRP Report 500*, Vol. 12

Offset T-Intersection



Targeted Crashes – Patterns

Each option has the ability to address a different type of crash; therefore, more information should be sought from the referenced strategies in the *NCHRP Report 500* series.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

The implementation time for many of these countermeasures will be several years in most situations. The cost can be high, especially in densely developed urban areas. The cost to implement in rural areas is typically less for several reasons, including less complex traffic staging and cost of right of way. The strategies that typically have the shortest implementation time and lowest cost include all-way stop control and removing unwarranted signals.

Some of the presented design and traffic control options may be new to area residents. There may be a need to create and institute education campaigns to help motorists utilize the intersections.

Effectiveness*

Following is information on the effectiveness of several strategies. More information is available for related strategies in *NCHRP Report 500* series:

- Create Offset T-Intersection: Offset accident rates are approximately 40% of the accident rate at comparable four-legged intersections.
- Remove Offset T-Intersection: May reduce crashes involving left-turning traffic from the major road onto the cross street at each T-intersection. May reduce or eliminate problems with insufficient spacing between existing offset T-intersections resulting from increased traffic.
- J-Turn: Up to 90% reduction in angle crashes experienced at rural expressway intersections.
- Roundabouts: At an unsignalized location, roundabouts can reduce all crashes by 38%, injury crashes by 76%, and fatal and severe injury crashes by 90%.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategies 17.1 B14, B15, B17, E3, F1, F2, F3

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategies 17.2 A7, B4, B5

I.10) Improve Signal Timing and Driver Awareness of Signals (P,T)

Strategy Overview

A suite of countermeasures to improve the safety performance of signalized intersections by improving signal timing and driver awareness of signals.

Enhancements

- Improve the safety and operation of traffic signals using multiphase operation, optimizing clearance intervals, coordinating signals in a corridor, and utilizing emergency vehicle preemption.
- Increase the visibility of the traffic signal using larger lenses (12-inch), overhead mast arms, activated advanced flashers, additional signal heads, back plates, etc.

A signalized intersection may benefit from these countermeasures. Signals located in unexpected areas (such as rural traffic signals, first traffic signal in the rural-to-urban transition, etc.) are locations that may benefit most from the visibility countermeasures.

Targeted Crashes – Patterns

- Angle, rear-end, and left turn crashes.
- Some angle and rear end crashes can be mitigated by improving the conspicuity of signals and by giving additional advance notification prior to signals.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☐ Collector	☒ Collector
☐ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

Implementation of signal timing enhancements may take as little as a few months at locations with current systems and the appropriate geometry (such as turn lanes in place). Implementation could extend up to several years if new equipment or roadway changes are necessary. Likewise, the cost of the strategy can be variable depending on the site conditions; ranging from low for simple engineering studies and new timing plans -- to moderate if new equipment is necessary.

Improving signal visibility can take only a few months and have a low cost for most locations.

Coordination with law enforcement and emergency responders will be necessary during implementation of a preemption system.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Effectiveness*

A California study reported a 35% average reduction in total crashes when left-turn lanes and left-turn phasing were implemented, as compared to an estimated 15% reduction when only left-turn lanes were installed.

A New York study found a 9% reduction in multi-vehicle crashes and a 12% reduction in injury crashes after change (clearance) intervals were lengthened to meet ITE recommendations. The study also showed a 37% reduction in related pedestrian and bicycle crashes.

Optimized signal coordination has been found to result in a 25% to 38% drop in intersection crashes.

Installation of preemption systems has been shown to reduce response times 14% to 50%. Preemption also credited with a 70% drop in emergency vehicles crashes at signals in one city.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategy 17.1 D3

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategies 17.2 A1, A2, A4, A5, D2

I.11) Improve Access Management (T)

Strategy Overview

Reduce the number of intersection and access point-related crashes by reducing the number of conflict points or to at least separate intersections and/or driveways so that influence areas do not interact.

Enhancements

- Control or manage access to adjacent land use (such as driveway frequency and location)
- Spacing of intersections (such as closing and/or diverting traffic from unsignalized intersections to signalized intersections or interchanges).
- Prohibit maneuvers that have demonstrated a higher risk (such as left turns or minor street crossings) by closing medians, using channelizing islands or signing restrictions.

Proper corridor access management, including the frequency of intersections, can improve safety, and can likely improve operations.

Targeted Crashes – Patterns

- Rear end, sideswipe (that is, a vehicle slowing to turn into a driveway is rear-ended or sideswiped by a vehicle going straight)
- Angle (that is, a vehicle turning out of a driveway hits a vehicle on the street)
- Left-turn (that is, a vehicle trying to turn left into a driveway is hit by an oncoming vehicle)

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☐ Local	☐ Local

Implementation Time and Issues, Costs, and Associated Needs

Implementation may take a few months to several years, depending on the selected solution, size of the project, extent of the agency's ability to make changes to access, and cooperation by land owners.

Similarly, the cost may be as low as several thousand dollars to erect signs to restrict turn movements.

Access management projects can require substantial outreach and education to affected residents or business owners. An access change is often a sensitive subject and rarely will all parties involved be content to give up direct access, even if it may improve safety and traffic operations.

Effectiveness*

Access management is reported to be "considered effective and has been addressed in published literature, but there is no consensus on quantitative estimates of its effectiveness." The effectiveness of any access improvements will be dependent on the size of the problem at the location fixed and the ability of the specific strategy deployed to effectively manage vehicle movements. However, studies from Minnesota[1] and Iowa[2] have suggested that 30% to 40% reduction in crash rates can be expected.

[1] Preston, H., D. Keltner, R. Newton and C. Albrecht. *Statistical Relationship Between Vehicular Crashes and Highway Access*. Minnesota Department of Transportation. St. Paul, Minnesota, August 1998.

[2] Maze. T., D. Plazak, P. Chao, J. Evans, E. Padgett, J. Witmer. *Access Management Research and Awareness Program: Phase IV*. Center for Transportation Research and Education, Iowa State University. Ames, Iowa, November 1999.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategies 17.1 A1, A2, B11, B12, B13

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategies 17.2 A3, F1, F2

I.12) Convert 4-Lane Undivided Roadways to 3-Lane Roadways (T)

Strategy Overview

Converting a 4-lane undivided road to a 3-lane road is often referred to as a “road diet” and is typically done to improve operations of a corridor. For example, the inside lanes of an undivided 4-lane roadway -- typically operate as defacto turn lanes, blocking vehicles continuing straight and causing lane changes as vehicles swerve around stopped vehicles.

Enhancements

- At certain volumes, traffic may actually operate “smoother” if two through lanes and a two-way left-turn lane (TWLTL) or marked channelized left-turn lanes are provided instead.
- Positive safety effects due to simplifying geometry and reducing intersection conflict points. Bicycle shoulder lanes can also be added.

Road diets are applied to urban or suburban corridors — typically a minor arterial or collector — but can be used in some rural situations.

Targeted Crashes – Patterns

- Rear end crashes – especially turning left into driveways or at intersections without turn lanes.
- Left-turn crashes – drivers that selected an unsafe gap because they felt “pressured” by vehicles waiting behind.
- Sideswipe-same direction crash – drivers swerving to avoid a rear-end crash.

Recommended Areas for Application

Rural	Urban
☐ Arterial	☒ Arterial
☐ Collector	☒ Collector
☐ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

This strategy can often be instituted with simple lane restriping of the existing roadway and erecting complementary signing along the corridor. Therefore, implementation will be low-cost and can be completed in under a year.

While implementation is typically simple, outreach may need to be made to residents and business along the corridor. Removing a through lane in each direction to increase capacity and safety is often not intuitive and could be poorly received by the public if appropriate outreach is not conducted.

Also, while TWLTL have been used around the country, it is possible some areas may not be familiar with the technique. If it is believed this is the case, then education of motorists on the proper use of a TWLTL should be considered.

Effectiveness*

At the time of writing the *NCHRP Report 500* series, one of the noted issues with this strategy is the lack of quality before-after studies. In a cross-classification study, a 3-lane with a TWLTL had a crash rate (crashes per million vehicle miles) of 1.56 in commercial areas and 1.64 in residential areas. In comparison, an undivided 4-lane had crash rates of 2.85 and 0.97, respectively. This is a 45% reduction in a commercial area for the 3-lane design.

A recent before-after study in Iowa evaluated 4-lane to 3-lane conversions. The study found a 21% reduction in crash frequency and 29% reduction in crash rate. The Bayesian statistical analysis found reductions of 25% in crash density and 19% in crash rate. Major injury crashes at the converted sites were reduced by 11%, minor injury crashes by 30%, and possible injury crashes by 31%.

* More information and references are available in the related strategy in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy and Other Resources

For more information and references, refer to the following strategy in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 4: *A Guide for Addressing Head-On Collisions* — Strategy 18.1 A4

Four-Lane to Three-Lane Conversions – Tech Transfer Summary. http://www.ctre.iastate.edu/pubs/t2summaries/4-3_lane.pdf. Center for Transportation Research and Education, Iowa State University. Ames, Iowa, April 2006.

I.13) Reduce or Eliminate Intersection Skew (P)

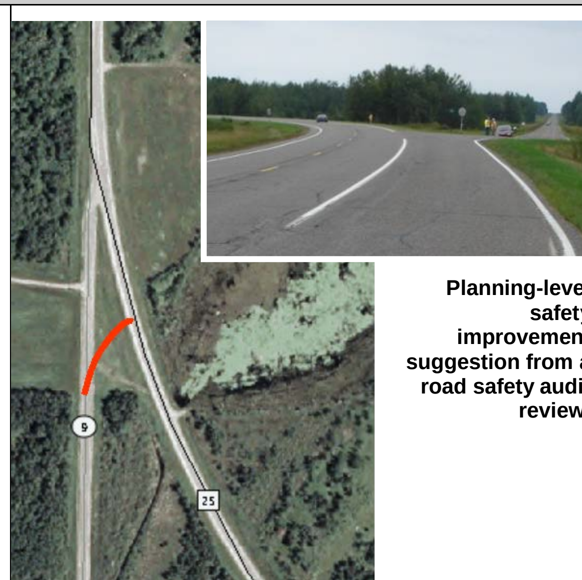
Strategy Overview

Intersection skew can have several noticeable impacts on intersection safety. A common issue is the difficulty drivers may have turning their head, neck or body to better view approaching traffic, especially at stop-controlled approaches at unsignalized intersections.

Enhancements

- Locations with large amounts of skew may experience several other problems, which are described in *NCHRP Report 500*, Volume 5, Strategy 17.1 B16.

Strategies are usually considered for rural unsignalized intersections, but also apply at signalized and/or unsignalized urban intersections.



Planning-level safety improvement suggestion from a road safety audit review.

Targeted Crashes – Patterns

- Crossing path crashes, including where a minor street vehicle is hit by a vehicle on the major street while turning or crossing.
- Vehicles turning left may misjudge the additional distance to cross when turning through a skewed intersection and be hit by an oncoming vehicle.
- Vehicles that turn too fast through either the obtuse or the acute angle may lose control — overturning or running off the road.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☐ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

Realignment of an intersection approach will likely take several years and will probably be at least a moderate-cost improvement. Therefore, this may be considered as a stand-alone safety project for either high-volume or high-speed cross-streets; likely arterials or collectors. However, low-volume cross streets could be realigned cost-efficiently during reconstruction projects.

Time should be planned into the schedule to coordinate with neighboring residents and business owners, especially those directly affected by right-of-way acquisition.

Effectiveness*

For eliminating skew at an unsignalized intersection, an expert panel developed the following equations.

$CMF = e^{(0.0040 * SKEW)}$ ➔ For a 3-legged intersection

$CMF = e^{(0.0054 * SKEW)}$ ➔ For a 4-legged intersection

CMF = crash modification factor

SKEW = Intersection skew angle (degrees); absolute difference between 90 degrees and the actual intersection angle.

For example, the CMF for a T-intersection with a 30-degree SKEW is 1.13. Eliminating the skew would reduce the CMF to 1.0; approximately a 13% reduction in expected crashes. If the intersection has four legs with a 30-degree SKEW, the CMF is estimated to be 1.18 and eliminating the skew may reduce crashes 18%.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 5: *A Guide for Addressing Unsignalized Intersection Collisions* — Strategy 17.1 B16

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* — Strategy 17.2 B4

I.14) Red-light Enforcement Programs (P)

Strategy Overview

Over 200 jurisdictions in the United States have found that red-light camera programs complement engineering and educational efforts to reduce crashes at intersections.

The system connects a processor to the traffic signal, vehicle sensors, and one or more cameras. When the system determines that a vehicle will likely fail to stop for a solid red traffic signal, a photograph (some systems use digital images or video) is taken of the vehicle prior to entering the intersection and again as it continues into the intersection. The violation images contain data to describe key elements such as the date, time, and location of the offense and how long the signal had been red. Later, an individual reviews the photograph to determine if it clearly shows a violation of the law. A citation may then be issued based on the applicable law, which the recipient of the citation has a right to contest.

Some systems only capture the rear of the vehicle based on laws that hold the vehicle owner responsible for the violation. In locations where the driver is held accountable, systems capture the front and rear of the vehicle to identify the vehicle registration and the driver.

In jurisdictions where automated enforcement is not allowed, agencies are using confirmation lights which aid officers to more efficiently conduct traditional red-light running enforcement.

Targeted Crashes –Patterns

- Right angle crashes at intersections where red-light violations had been a problem.

Red-light camera programs reduce the number of vehicles committing red-light violations by targeting drivers that disobey the red signal.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☐ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

The red-light camera system is one part of a program that includes public awareness and a careful site selection process. Once implemented, the program should be monitored to ensure it is achieving the desired effects.

It is important to note that most parts of the United States require specific legislation to permit automated red-light cameras for enforcement. Many states already permit this type of enforcement. Some states allow local jurisdictions to enact this type of a program without a state law. If a jurisdiction decides a red-light camera will help their community, it is important to determine what legislative needs exist based on their location. Should a legislative change be required, it is important to work closely with community leaders and legislators to draft appropriate legislation.

Communities in the U.S. have used several different financial strategies to implement these programs. A few have purchased all of the required equipment and operated the system themselves. Most locations have partnered with private companies to supply and maintain the equipment. Many companies will install the systems at their own expense and allow an agency to start paying only after fines are received from violators. Many of the programs in the United States have been funded completely through traffic violators paying fines.

Effectiveness*

Multiple studies have shown that red-light cameras have lead to reductions in (often more severe) right-angle crashes and increases in (often less severe) rear-end crashes. Multiple studies have shown a net crash cost benefit. A 2005 FHWA study of red-light camera systems in seven U.S. cities concluded each red-light camera resulted in an average crash cost reduction of $38,000 annually by decreasing right-angle crashes by 25% and increasing rear-end crashes by 15%.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy and Other Resources

For more information and references, refer to the following strategy in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections* – Strategy 17.2E3

Decina, L., Thomas, L., Srinivasan, R. and Staplin, L. *Automated Enforcement: A Compendium of Worldwide Evaluations and Results*. National Highway Traffic safety Administration. July 2007.

Information and a contact on Florida's use of confirmation lights is available in the 2005 Safety Best Practices Guide from the National Roadway Safety Awards (http://www.roadwaysafetyawards.org/Docs%20and%20Downloads/2005SafetyBestPracticesGuide.pdf).

II.1) Improve Advanced Curve Warning and Curve Delineation (P,T)

Strategy Overview

Improve the delineation of a horizontal curve and the driver's awareness of the curve.

Enhancements

- Install or use larger chevrons or delineators.
- Use larger advance warning signs.
- Special pavement markings (such as converging transverse markings).
- Install curve lighting.
- Wider/brighter lane lines.
- Consistent advance warning to improve driver expectancy is important to effectiveness. It is important to not use excessively, especially at locations where no added warning or delineation is needed, otherwise drivers may become desensitized and begin to ignore.

These countermeasures are appropriate for a variety of conditions — high-speed or low-speed; urban or rural; sharp curve or gentle curve, etc.

Targeted Crashes – Patterns

Crashes on horizontal curves—where either the driver could not maintain control through the curve or did not see the curve:

- Run-off the road.
- Head-on.
- Sideswipe (opposing).
- Overturn.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

For a single curve, most countermeasures could be installed in a few months and at a relatively low cost. Implementation time and cost will increase if deployed along a long corridor or as part of a widespread proactive program.

Some studies have found that some enhancements can result in higher travel speeds since drivers have the perception of improved visibility.

While curve warning and delineation can be used at any location, a cost-effective approach may include a focus on high-speed curves with either an existing crash problem or curves with characteristics that are common to curves with crash problems (such as the first curve at the end of a long tangent, small radius curves, etc.)

Effectiveness*

Effectiveness from research studies shows a variety of results and some studies only looked at vehicle speeds as a crash surrogate. More information on related studies is available in the *NCHRP Report 500* series. A summary of key findings includes the following.

- An early study (1966) of post-mounted delineators on rural 2-lane curves showed a 15% reduction in run-off the road crashes.
- An early study (1968) found an 18% crash reduction at horizontal curves with curve warning signs and a 22% crash reduction after installation of both curve warning and advisory speed signs.
- General effectiveness information regarding the general use (not specific to curves) of pavement markings is available in Strategy II.2.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies and Other Resources

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 6: *A Guide for Addressing Run-Off-Road Collisions* — Strategy 15.1 A4

NCHRP Report 500, Volume 7: *A Guide for Reducing Collisions on Horizontal Curves* — Strategies 15.2 A1, A2

A recent FHWA publication for low-cost horizontal curve treatments:
McGee, H., and F. Hanscom. *Low-cost Treatments for Horizontal Curve Safety*. FHWA-SA-07-002. Federal Highway Administration, Washington, D.C. December 2006.

II.2) Improve Pavement Markings and Delineation (T)

Strategy Overview

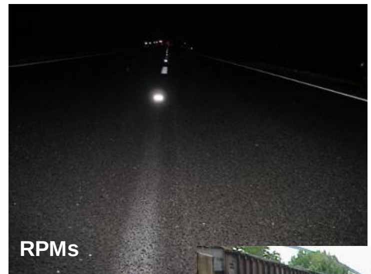
Provide drivers with lane and edge of roadway delineation, especially along medium and high volume roadways and on multi-lane roads.

Enhancements

Lane lines can be enhanced to aid drivers and improve safety, especially during nighttime or adverse weather conditions.

- Wider lane lines (8-inch over 4-inch).
- Wet retro reflective material.
- Durable material.
- Raised pavement markers (RPMs).
- Recessed markings.
- Adding edge lines to low-volume roads.

These strategies are useful in a wide variety of locations — rural or urban, high-volume or low-volume, high-speed or low-speed. In addition, these applications would be expected to achieve the best results if applied to a corridor or entire road system.



Targeted Crashes – Patterns

Crashes where a vehicle unintentionally left their lane because they could not see the lane markings or edge of roadway:

- Head-on
- Sideswipe (opposing direction)
- Run-off the road crash.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

A variety of products are available for use, and each may be best suited for a specific application, but most products could be implemented along a corridor within a few months. Furthermore, the project cost may be as low as $500 per mile or as high as $5,000 per mile. A large deployment, such as a system-wide implementation, will require more time to complete (possibly several years in a phased implementation) and the aggregate cost could grow.

While some materials such as durable pavement markings may actually require less maintenance, this may not hold true for other applications. For example, it is best to have a routine inspection of raised pavement markers to ensure they won't become dislodged from the roadway and become and may affect passing motorists (such as a snow plow dislodges an RPM).

Effectiveness*

- Centerlines profiled thermoplastic strips have been reportedly used extensively by California and Texas, but no formal studies are available.
- Studies on the safety benefit of RPMs have shown positive results when used at high-crash locations; however, caution is needed before using on a system-wide basis since there is no information to confirm the effectiveness. In Ohio, RPMs reduced crashes by 9% and injuries by 5%. In New York, RPMs reduced crashes by 19% on high-crash roads.
- Some studies have found that the use of RPM's on curves can result in higher travel speeds since drivers have the perception of improved visibility.
- Studies conducted on the safety benefit of wider pavement markings have not been definitive. A New York study found 8-inch edge lines reduced total and injury crashes by 5% and fixed object crashes by 16% when compared to installations with 4-inch edge lines.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 4: *A Guide for Addressing Head-On Collisions* — Strategy 18.1 A2

NCHRP Report 500, Volume 6: *A Guide for Addressing Run-Off-Road Collisions* — Strategy 15.1 A6

II.3) Install Shoulder, Edgeline or Centerline Rumble Strips (P,T)

Strategy Overview

Use rumble strips on the shoulders or on the centerlines (of undivided roadways) to alert drivers when they unintentionally leave their travel lane. Drivers are alerted by the noise and vibration that occurs when driving over the rumble strips.

Enhancements

- Edgeline rumble strip, where the edgeline is placed directly over the rumble strip. This is also known as the rumble stripe or humming edgeline paint. Advantages of this technique is the improved visibility during dark or wet conditions and the rumble strip increases the life of the pavement marking by protecting it from snow plows.
- Centerline rumble strips on undivided roadways.

Application of this strategy is typically used along rural high-speed corridors. Rumble strips are normally not used in urban/suburban areas.

Targeted Crashes – Patterns

Lane-departure crashes involving a vehicle that unintentionally leaves the travel lane:

- Run-off the road crashes.
- Head-on crashes on undivided roads.
- Across median crashes on divided roadways.
- Sideswipe-opposing crashes.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☐ Arterial
☒ Collector	☐ Collector
☒ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

For corridors that have the width and pavement quality needed for rumble strips, implementation can take as little as a few months and cost as little as a few thousand dollars a mile. Rumble strips can be especially cost-effective if combined with planned maintenance projects, such as an overlay.

Some needs that accompany rumble strips may include training for the engineers and technicians that prepare the design, communication with motorcycle and bicycle communities to address their concerns, and confirming implementation is at locations where noise will not be a significant concern with adjacent land owners.

Effectiveness*

Past studies have found varying results for most strategies, but some general guidance regarding expected effectiveness is provided below.

- Centerline rumble strips on 2-lane roadways have been reported to have a 30% to 60% head-on crash reduction on roadways that were high crash sites prior to implementation. Note: treatment of only high-crash sites does not account for regression to the mean, so the results may be slightly over estimated.
- It has been estimated by FHWA that shoulder rumble strips will have a 20% to 50% reduction in the number of run-off the road crashes on freeways. The effectiveness on 2-lane roadways has not been conclusive, but has been speculated to be in the range of a 20% to 30% reduction in run-off-the-road crashes.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 4: *A Guide for Addressing Head-On Collisions* — Strategy 18.1 A1

NCHRP Report 500, Volume 6: *A Guide for Addressing Run-Off-Road Collisions* — Strategies 5.1 A1, A2

NCHRP Report 500, Volume 7: *A Guide for Reducing Collisions on Horizontal Curves* — Strategies 15.2 A4, A5

II.4) Minimize or Eliminate Pavement Edge Drop-offs (P,T)

Strategy Overview

When unpaved shoulders are not maintained, the erosion of the shoulder forms a drop-off at the pavement edge. One of the main difficulties of a drop-off is when a driver doesn't properly reduce speed when trying to get back on the road. When a driver tries to overcome the "scrubbing" on the inside of the tire, they can over-correct and lose control—potentially resulting in a roll-over crash or crashes with oncoming traffic. Severe erosion or rutting of the shoulder may cause a driver to lose control and result in a run-off the road crash.

Enhancements

- Pave the shoulder and (widen if needed) to move the potential drop-off farther from the travel lane.
- Pave a fillet, called a Safety Edge (between 30 degrees and 45 degrees) at the pavement edge to ease the transition from the shoulder to the road.

Targeted Crashes – Patterns

- Run-off the road (left side or right side).
- Head-on, sideswipe (opposing direction).
- Overturn crashes.

Recommended Areas of Application

Rural	Urban
☒ Arterial	☐ Arterial
☒ Collector	☐ Collector
☐ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

Application of this strategy is typically used along rural and/or high-speed corridors.

The time and cost to implement paved and widened shoulders will depend mostly on the size of the project. Shoulder paving projects cost an estimated $100,000 per mile when a gravel shoulder exists.

The cost to add a safety edge is negligible since only an attachment needs to be added to the paving machine. This would typically be added as part of overlay and construction projects, therefore, the time to implement system-wide will depend on the maintenance and replacement schedule.

Effectiveness*

- The expected effectiveness of shoulder paving depends on the initial shoulder width and surface type. The highest expected reduction in related crashes is nearly 12%.
- The expected effectiveness of shoulder widening depends on the initial shoulder width, final shoulder width, shoulder surface type, and average daily traffic (ADT). The scenario for the greatest expected reduction is a road at an ADT of over 2,000 vehicles per day, with no shoulders that is widened to have an 8-foot paved shoulder; a 42% reduction in single-vehicle run-off-road and multiple vehicle opposite-direction crashes is expected.
- The expected effectiveness of the safety wedge is yet unstudied. One study proposed that a 45-degree wedge at the lane edge could significantly reduce the target crashes, even where the shoulder is unpaved and eroded.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 6: *A Guide for Addressing Run-Off-Road Collisions* — Strategy 15.1 A8

NCHRP Report 500, Volume 7: *A Guide for Reducing Collisions on Horizontal Curves* — Strategy 15.2 A6

II.5) Use Alternating Passing Lanes or 4-Lane Sections (T)

Strategy Overview

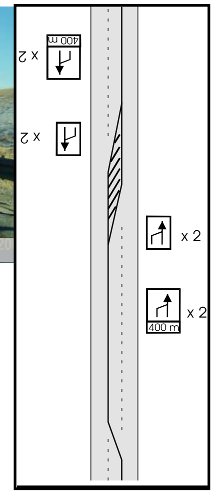
Passing maneuvers pose a safety risk on busy highways. Alter road geometry to facilitate safe passing.

Enhancements

- Create a 4-lane or 3-lane roadway at key sections. The length of the passing section should be long enough to allow for several passing maneuvers to be completed by drivers.
- Create an alternating passing lane. The 2+1 roadway used in Europe is a 3-lane roadway where the center lane is an alternating passing lane. Some installations use cable median barriers to separate opposing directions.

This strategy could be used in a variety of situations; however, the primary locations will be the rural 2-lane roadway or hilly/mountainous terrain, especially where high volumes create difficulties passing and added capacity is needed to improve operations.

Passing Lane in Wyoming



Targeted Crashes – Patterns

Passing-related crashes, most likely on rural 2-lane roadways:

- Head-on.
- Opposing sideswipe.

Could also involve a run-off the road or rear end crash.

Recommended Areas for Application

Rural
- ☒ Arterial
- ☒ Collector
- ☐ Local

Urban
- ☐ Arterial
- ☐ Collector
- ☐ Local

Implementation Time & Issues, Costs, and Associated Needs

Over extended segments, reconstruction would typically be necessary to implement this strategy. This factor will likely result in an implementation time of several years or more. This strategy may have a high cost over extended segments. For use at key (shorter) segments, the implementation time and cost can be reduced.

The use of passing lanes, especially on long or steep up-grades is fairly common and typically only requires basic signing to advise the driver. However, the design of a 2+1 roadway may require some added public education. Also, efforts should be made to work with emergency responders to provide the ability to make u-turns at important locations when the design includes a cable median barrier.

Effectiveness*

- It has been estimated that a one-way passing lane could reduce total (not just head-on) crashes by 25% over the area improved. Furthermore, a short 4-lane section is estimated to reduce total crashes by 35% over the length of the improvement. Respectively, fatal and injury crashes may be reduced 30% and 40%.
- The use of 2+1 roadways in Europe have seen crash rates approximately 25% to 50% lower than the traditional 2-lane highway. Further, experience in Europe points to the use of cable median barriers for the 2+1 design as successful at reducing fatal head-on crashes.

* More information and references are available in the related strategy in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy

For more information and references, refer to the following strategy in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 4: *A Guide for Addressing Head-On Collisions* — Strategy 18.1 B1

II.6) Include a Narrow Median on 2-Lane Roadways (T)

Strategy Overview

Head-on crashes on undivided roadways may result from a driver attempting a passing maneuver or by inadvertently crossing the centerline. A narrow median provides a recovery zone before entering the opposing travel lanes.

Enhancements

- Depending on the width of the median and the access plan, incorporate a median barrier into the design.
- Incorporate centerline rumble strips into the median as shown in the photo.
- If paved shoulders are in place, restripe with narrower shoulders or lanes (easiest option).
- Where paved shoulders are not already provided, widen the pavement before adding a narrow median.

This strategy is typically for 2-lane roadways, but can be used on undivided multi-lane roads. While commonly used in rural areas; urban/suburban roads with opposite direction crashes are candidates.

Targeted Crashes – Patterns

Opposite direction crashes where the driver inadvertently crosses into the opposing travel lanes:

- Head-on
- Opposing sideswipe.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☐ Collector
☐ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

On roads that have sufficient width to accommodate a narrow median, the strategy could be implemented in as little as a few months by restriping the roadway. This situation would typically be a relatively low-cost project. Roads that do not have sufficient paved width to accommodate the median will require additional time and cost in order to implement. Other factors that may increase the time and cost of implementation include adding a median barrier, especially if special design considerations must be given to provide access.

If centerline rumble strips are included in the median, communication with motorcycle and bicycling communities is recommended.

Effectiveness*

In Volume 4 of the *NCHRP Report 500* series, one case study was reviewed of a narrow buffer median (with median guardrail) implemented on two 2-lane roads in Maryland. The before-after analysis did show a 50% reduction in total crashes and head-on crashes, but regression to the mean effects may have overestimated the crash reduction since the improved segments were high-crash areas.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 4: *A Guide for Addressing Head-On Collisions* — Strategy 18.1 A5

NCHRP Report 500, Volume 7: *A Guide for Reducing Collisions on Horizontal Curves* — Strategy 15.2 A11

III.1) Remove or Relocate Fixed Objects (P)

Strategy Overview

Provide a recovery area free of fixed objects and with slopes that allow a driver to safely stop or regain control. This strategy focuses on collisions with fixed objects that can be removed or moved further from the roadway.

Enhancements

- Move utility poles, placing utilities underground.
- Remove trees.
- Extend a culvert to move the headwall.
- Place sign/lighting/signal structures further from the road.

Note: Relocating a fixed object to increase the clear zone does not guarantee a vehicle won't hit the relocated object. However, it is expected to reduce the severity of a crash as a vehicle may have a reduced speed.

This strategy is appropriate for all classifications in rural, urban and suburban environments. However, the desired minimum clear zone recommended in the AASHTO *Roadside Design Guide* depends on design speed, traffic volume, grade of side slope, and road curvature.

Top photo shows Highway 38 in Minnesota with an inadequately defined clear zone. Bottom photo shows Highway 6 in Minnesota with adequate clear zone

Targeted Crashes – Patterns

- Single-vehicle crashes where the vehicle leaves the roadway and collides with a fixed object.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

The time and cost of removing or relocating fixed objects from the roadside will vary depending on the length of the corridor, existing width of clear zone and right-of-way, and the type of object. For example, the cost of cutting trees and shrubs in the clear zone could be accomplished in a few months at a low cost and would be expected to take much less time and cost compared to placing utilities underground.

Before removing some or all fixed objects in a clear zone, the context of the corridor should be considered. For example, the stakeholders for roads that pass through a National or State Park, or forest may not want all trees removed within the recommended minimum clear zone. Instead, select cutting or defining a reduced clear zone may be better given the context. Similar issues arise in an urban context where tree plantings are often aesthetically desirable to a community.

Effectiveness*

Studies that investigated the impacts of creating larger clear zones by removing or relocating objects were found to have favorable results. On 2-lane roadways where the existing clear zone was less than 10 to 15 feet, impacts of clear zone widening were studied for run-off-the-road, head-on, and sideswipe crashes. Increasing the clear zone by 5 feet is expected to reduce related crashes by 13%, and a 20 feet increase in clear zone is expected to reduce related crashes by 44%.

Exhibit V-25 and Exhibit V-26 of *NCHRP Report 500*: Volume 6 provide more information on expected safety benefit of clear zone widening.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 3: *A Guide for Addressing Collisions with Trees in Hazardous Locations* — Strategy 16.1 B1

NCHRP Report 500, Volume 6: *A Guide for Addressing Run-Off-Road Collisions* — Strategy 15.1 B2

NCHRP Report 500, Volume 7: *A Guide for Reducing Collisions on Horizontal Curves* — Strategy 15.2 B2

NCHRP Report 500, Volume 8: A Guide for Addressing Collisions Involving Utility Poles — Strategies 16.2 A1, A2, C2

III.2) Shield Drivers from Roadside Fixed Objects (P,T)

Strategy Overview

When steep slopes can not be flattened to prevent rollovers and fixed objects can not be removed or relocated, then an option is to provide alternatives such as shielding drivers from roadside obstacles.

Enhancements

- Install guardrail to shield the obstacle to reduce the crash severity.
- Replace out-dated, damaged, or improperly installed guardrail and guardrail terminals with newer systems that meet current crash test standards.

Note: Adding or replacing guardrail will not prevent the crash, but is expected to reduce the crash severity.

This strategy can be used on any roadway where shielding steep slopes or fixed objects will enhance safety. High-speed roadways (45 mph or greater) are where guardrail will likely be the most valuable; where speed may be a contributing factor to the severity of the crash.

Targeted Crashes – Patterns

- Single-vehicle crashes where the vehicle leaves the roadway and collides with a fixed object or overturns on a steep slope.

Recommend Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

The time to implement at a single location will typically be a few months or less. Implementation along a corridor or across a system may require more time. The cost of most projects will be relatively low, but large projects or system-wide improvements may be a moderate cost. The following costs represent an average expected cost, but will vary depending on specific site conditions, size of the project, and the type of safety feature selected:

- Impact attenuator: $20,000
- Guardrail terminal: $1,500
- Guardrail transition (connection to bridges or concrete barrier): $1,000
- W-beam or cable guardrail: $75,000/mile

Effectiveness*

Crash frequencies may increase with the installation of additional barrier, especially if relatively close to the roadway, but crash severities should decrease as impacts with safety hardware are much less likely to result in a fatal or serious injury as compared to an unimpeded run-off-road crash. In a study of collisions with median barriers, it was found that there was no injury or fatality in 82% of collisions with strong-post barriers, 83.8% of collisions with concrete barriers, 91% collisions with weak-post barriers and 88% of collisions with barriers of other design. Proper installations of guardrail with the new generation of terminals should be expected to have a similar safety record. The safety benefit of updating out-of-date guardrail terminals is unknown. The effectiveness will depend on the number and type of out-dated terminals replaced.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 3: *A Guide for Addressing Collisions with Trees in Hazardous Locations* — Strategy 16.1 B2

NCHRP Report 500, Volume 6: *A Guide for Addressing Run-Off-Road Collisions* — Strategies 15.1 C1, C2

NCHRP Report 500, Volume 7: *A Guide for Reducing Collisions on Horizontal Curves* — Strategies 15.2 B4, B5

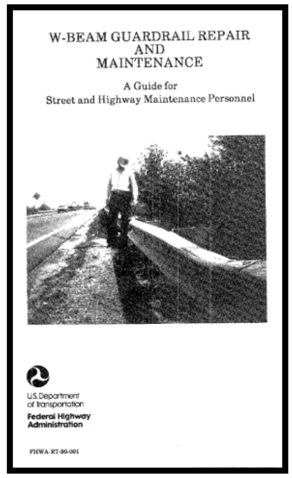
NCHRP Report 500, Volume 8: *A Guide for Addressing Collisions Involving Utility Poles* — Strategy 16.2 A4

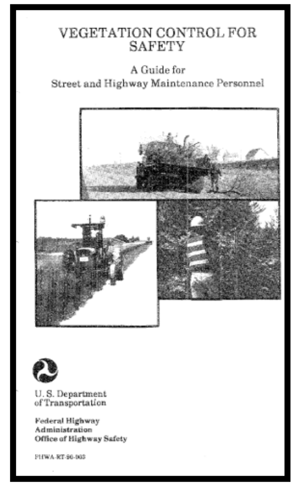
III.3) Develop, and Revise Guidelines Related to Fixed Objects (P,T)

Strategy Overview

Develop, revise, implement policies, and guidelines related to placing fixed objects in the roadside to prevent a run-off the road crash from resulting in a serious injury or fatality. Guidelines should ideally consider all fixed objects in the right of way, and especially those that fall within the clear zone or at other locations — such as the outside of a curve. Yet, guidelines should permit engineers to consider areas of a sensitive context (for example, parks).

Some policies and guidelines to consider include planting of trees, locating utility poles, signs, sign structures, piers, culvert openings/headwalls, etc. — for both new construction and reconstruction projects. Other guidelines should address maintenance activities, especially keeping trees from being planted too close to the roadway or allowing wild trees to grow close to the road.





Targeted Crashes – Patterns

- Crashes where a vehicle leaves the roadway and collides with a fixed object in the roadside.

The fixed object would not have been placed in the roadside (or in a safer location) had policies and guidelines related to design, construction, or maintenance been developed and followed.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

The time to develop and approve guidelines and policies should take less than a year. This process can be accelerated by referring to guidelines previously developed by other agencies. This will reduce cost and staff time. It is also important to remember there will be ongoing cost and time to keep the guidelines current. There will be ongoing costs and more significant time will come in implementation, especially if significant changes or costlier techniques (such as placing utilities underground) are adopted.

It is likely there will be a need to communicate with the public and other stakeholders (such as public utilities) to increase awareness of the guidelines and gain their support. The communication can also direct individuals to the proper contacts when unsure how to apply the guideline or working in a difficult situation that may require an exception.

Effectiveness*

There is not a measurable safety benefit in preparing or updating policies and guidelines. Instead, the safety benefit is realized when the policies and guidelines are put into practice properly, consistently and throughout all stages of operating a roadway (design, construction, and maintenance).

Attributes of well designed policies and guidelines include: buy-in from upper management, widespread implementation (recognizing time will be needed to allow the program to mature), some situations are complicated and not fully anticipated, and sound technical quality.

Refer to the strategies on removing or relocating (Strategy III.1) fixed objects for more information on the expected safety benefit of providing a clear zone.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 3: *A Guide for Addressing Collisions with Trees in Hazardous Locations* — Strategies 16.1 A1, A2

NCHRP Report 500, Volume 8: *A Guide for Addressing Collisions Involving Utility Poles* — Strategies 16.2 B1, C1, C3

III.4) Design Safer Slopes and Ditches to Prevent Rollovers (P)

Strategy Overview

Design safer slopes and ditches to prevent rollovers, or reduce the severity when a vehicle leaves the roadway on a traversable roadside, thereby reducing the likelihood of a rollover. Rollovers may be caused by either a steep slope that makes it difficult to keep a vehicle upright or a moderate slope where a vehicle can overturn if the driver makes a sudden steering change at moderate or high speeds.

Enhancements

- Flatten sideslope to improve a driver's ability to maintain control of their vehicle and recover.
- Design grades around culverts and transverse slopes to present a minimal obstruction.
- Install culvert grates to prevent a tire from being snagged and causing a vehicle to overturn. (Note: Culvert grates should be sized to reduce clogging and facilitate drainage)

This strategy is especially effective for rural and high-speed roadways (speed limit of 45 mph or higher).

Targeted Crashes – Patterns

- Single-vehicle run-off the road crashes ending in a rollover.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☐ Arterial
☒ Collector	☐ Collector
☒ Local	☐ Local

Implementation Time & Issues, Costs, and Associated Needs

The time and cost to implement will depend on the site specific characteristics, but it may take one to two years to design and implement a project and with a moderate cost.

The AASHTO *Roadside Design Guide* defines three types of sideslopes. Slopes steeper than 1:3 are considered critical and will likely cause most vehicles to overturn. Slopes between 1:3 and 1:4 are considered non-recoverable (meaning that while traversable if clear, a driver likely won't stop before reaching the bottom) and should have a clear runout distance at the bottom. A recoverable slope is defined as 1:4 or flatter. However, note that the "Effectiveness" information does indicate that slopes at 1:5 or flatter have significantly lower rollover rates.

Effectiveness*

Rollover crashes are caused by more than just the design of the sideslope and ditch. Speed, vehicle characteristics, and driver reactions may cause the rollover instead of the road design. Therefore, even a perfectly flat roadside won't eliminate all rollovers.

A study of 1,800 miles of 2-lane rural roads in three states found slopes of 1:4 and steeper had rollover rates that were significantly higher than slopes with a slope of 1:5 and flatter. The same study found that sideslope flattening can reduce reported single-vehicle run-off the road crashes from 6% to 27%, depending on the before and after slopes.
Exhibit V-24 in *NCHRP Report 500*, Volume 6 has specific information on expected crash reductions for sideslope flattening. A before-after study in Washington found that sideslope flattening had a 25% to 45% reduction in reported run-off-the-road crashes.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 6: *A Guide for Addressing Run-Off-Road Collisions* — Strategy 15.1 B1

NCHRP Report 500, Volume 7: *A Guide for Reducing Collisions on Horizontal Curves* — Strategy 15.2 B1

IV.1) Provide Sidewalks/Walkways and Curb Ramps (P)

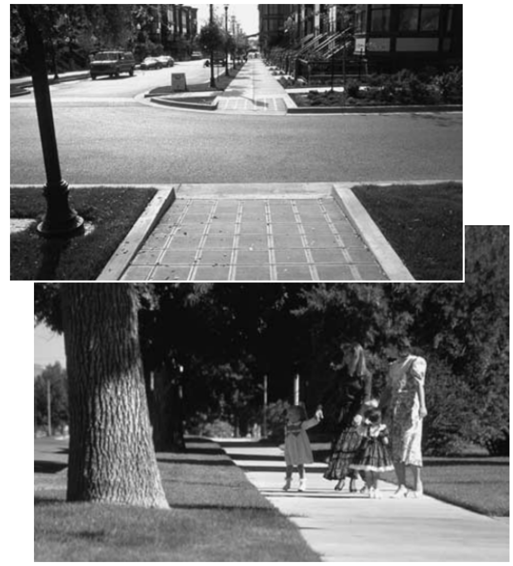
Strategy Overview

Sidewalks and walkways provide pedestrians with space to travel within the public right-of-way that is separated from roadway vehicles. They also provide places for children to walk, run, skate, ride bikes, and play away from the street. Sidewalks also improve mobility for pedestrians and provide access for all types of pedestrian travel to and from home, work, parks, schools, shopping areas, transit stops, etc. Compliance with the Americans with Disabilities Act (ADA) is required.

Enhancements

- Build curb ramps to provide transition in elevation between the sidewalk and roadway for people using wheelchairs, strollers, walkers, crutches, handcarts, and bicycles, as well as for pedestrians with mobility impairments who have difficulty stepping up and down high curbs.

This strategy is typically used for urban and suburban roadways.



Targeted Crashes – Patterns

- Pedestrian crashes where the pedestrian was walking along the street or highway or on shoulders.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☐ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

State and local design, planning, and zoning ordinances may need revision to require sufficient space for sidewalks and other pedestrian facilities. Funding needs to be earmarked for sidewalk improvements. Proper planning of pedestrian needs is also essential to set priorities for needed sidewalk installations and enhancements.

Costs for sidewalks will vary, depending upon factors such as width and materials used, but will generally be low cost and require minimal time to implement.

A buffer zone is desirable and should be provided to separate pedestrians from the street. In downtown or commercial districts, a street furniture zone can provide appropriate as a buffer zone. Parked cars and/or bicycle lanes can also provide an acceptable buffer zone. In more suburban or rural areas, a landscape strip is generally more suitable.

Effectiveness*

The presence of sidewalks on both sides of the street has been found to significantly reduce pedestrian crash risk, compared to locations where no sidewalks or walkways exist. Reductions of 50% to 90% of these types of pedestrian crashes have been found in previous research.

Physical design factors that were associated with a significantly higher likelihood of being a crash site were higher speed limit, the lack of walkable areas, and the absence of sidewalks. Taking into account speed limit and traffic volume, the likelihood of a site with a sidewalk being a crash site was 88% lower than a site without a sidewalk. Hence, the presence of a sidewalk clearly had a strong beneficial effect of reducing the risk of “walking along roadway” pedestrian crashes.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 10: *A Guide for Reducing Collisions Involving Pedestrians* — Strategy 9.1 A1

IV.2) Provide Bike Lanes and Bike Paths (T)

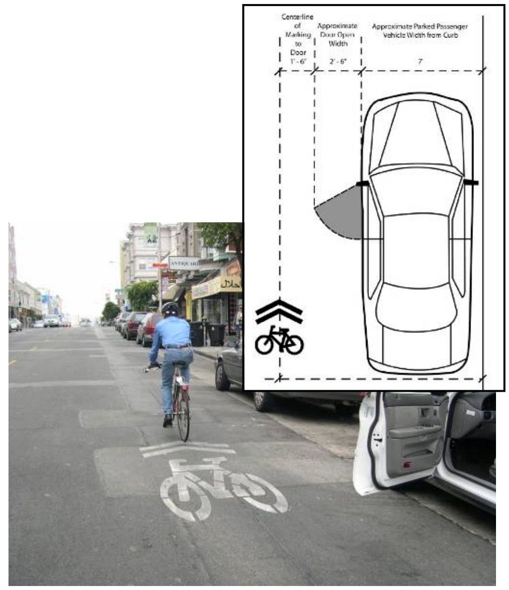
Strategy Overview

Provide multiple cues for both bicyclists and motorists that indicate preferential areas for each to travel along roadways. Striped bike lanes are used when it is desirable to delineate the available road space as exclusive or preferential for bicyclists. Roadway facilities that more clearly identify appropriate travel areas for all road users and their expected behavior may provide a safer environment for bicyclist travel along parallel paths and help reduce crashes.

Enhancements

- Create striped bike lanes to provide marked areas for bicyclists to travel along roadways. This allows for more predictable movements for both bicyclists and motorists.
- Build a bicycle path as a separate facility intended for bicycles and other non-motorized travel.

This strategy is typically used in urban and suburban areas, especially areas and corridors where bicycle commuting is relatively common.



Targeted Crashes – Patterns

- Collisions with bicycles where the bicyclists was traveling in the same direction as vehicle traffic.

Recommended Areas for Applications

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☐ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

Adding pavement markings to the roadway can be implemented in a very short time. Paved shoulders, if needed, require significantly more time to plan and construct.

The cost of installing a bike lane is approximately $5,000 to $50,000 per mile, depending on the condition of the pavement, the need to remove and maintain the lane lines, the need to adjust signalization, and other factors. It is more cost efficient to create bike lanes during street reconstruction, street resurfacing, or at the time of original construction.

Although bicyclists and motor vehicle operators understand how to ride or drive on roads with marked bike lanes, installation of other more innovative on-road bicycle facilities (for example, contraflow bike lanes, bike lane markings, and signing at intersections) may need to be accompanied by public information campaigns to clarify how they should be used.

Effectiveness*

Bike lanes have been found to provide more consistent separation between bicyclists and passing motorists than shared travel lanes. The presence of bicycle lane markings has also been shown from research to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist behavior, and enhanced comfort levels for both motorists and bicyclists.

Wide curb lanes provide an area sufficiently wide for both motor vehicles and bicyclists to use the lane. Research has shown that paved shoulders tend to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist riding behavior, and enhanced comfort levels for both motorists and bicyclists.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 18: *A Guide for Reducing Collisions Involving Bicycles* — Strategies B1, B2

IV.3) Provide Lighting and Paved Shoulders (T)

Strategy Overview

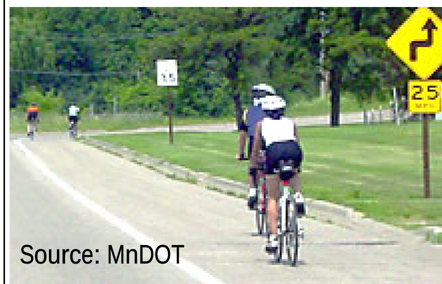
Provide paved shoulders and roadway lighting to enhance bicycle safety. Paved shoulders tend to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist riding behavior, and enhanced comfort levels for both motorists and bicyclists. Sufficient roadway illumination also helps nighttime bicyclists see surface conditions and obstacles or people in the path of travel. With good design, lighting can enhance safety of the bicycling as well as pedestrian environment and improve the ambience of areas of nighttime activity.

Enhancements

- Pave shoulders to provide a separated space for the bicyclist much like a bike lane.
- Install or improve roadway lighting to reduce crashes that occur under less-than-optimal light conditions.

Lighting is likely to be used in urban and suburban locations, but may be appropriate in some rural settings.

Rural improvements for bicyclists should be considered when there is a large number of crashes (especially nighttime and/or twilight) on routes with large bicycle volumes.


Source: MnDOT


Source: MoDOT

Targeted Crashes – Patterns

- Car-bicycle crashes.
- Bicycle crashes due to debris or obstacles in the road.

Improved lighting allows bicyclists to see the roadway, debris or potential obstructions, and increases the visibility of bicyclists to drivers in low-light conditions. Paved shoulders indicate preferential areas for bicyclists and motorists to travel along roadways.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☐ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

Lighting does not require a long development process. Lighting improvements can typically be implemented in less than 6 months. Paved shoulders require significantly more time to plan and construct.

Paved shoulder costs can be quite variable. Iowa DOT average contract prices for 2000 show a minimum design width of 1.2 meters (4 feet) of paved shoulder width to accommodate bicycle traffic was estimated at $44,000 per kilometer ($71,000 per mile). Lighting cost varies depending on fixture type, design, local conditions, and utility agreements.

Bicycle-tolerable edgeline rumble strips provide increased safety for motorists without generating excessive vibration for bicyclists. This allows more shoulder area for bicyclists, and possibly a narrower shoulder design.

Effectiveness*

Research has shown that paved shoulders tend to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist riding behavior, and enhanced comfort levels for both motorists and bicyclists.

Data from 5 years of North Carolina bicycle/motor vehicle crashes indicate that about one quarter of reported collisions and more than half of bicyclist fatalities occurred during non-daylight conditions, probably far exceeding the proportion of riding that occurs under these conditions. Similarly, estimates from Florida State University indicate that “nearly 60% of all adult fatal bicycle accidents in Florida occur during twilight and night hours even though less than an estimated 3% of bicycle riding takes place during that time period.

*More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 18: *A Guide for Reducing Collisions Involving Bicycles* — Strategies B1, B3, B5

IV.4A) Provide Intersection Traffic Calming Measures (P & T)

Strategy Overview

Traffic-calming encompasses a series of physical treatments meant to lower vehicle speeds and volumes by creating the visual impression that certain streets are not intended for high-speed or "cut-through" traffic. Thus, traffic calming may improve conditions for pedestrians and reduce vehicle-pedestrian collisions at intersections. Traffic calming measures can also make drivers aware of the presence and priority of pedestrian traffic, especially by utilizing marked crossing locations at intersections.

Enhancements

- Curb radius reduction.
- Mini-circle
- Curb extension.
- Raised intersections.

Traffic-calming treatments should be designed and applied under appropriate conditions, to maximize their effectiveness.

Information on U.S. experiences with various traffic-calming treatments can be found in ITE's *Traffic Calming: State of the Practice* (1999).

Targeted Crashes – Patterns

- Vehicle-pedestrian collisions at intersections

Recommended Areas for Application

Rural		Urban	
☐	Arterial	☐	Arterial
☐	Collector	☒	Collector
☐	Local	☒	Local

Implementation Time & Issues, Costs, and Associated Needs

It may take one or more years to implement these countermeasures. Traffic engineers often conduct engineering studies to determine whether one or more of these countermeasures should be used at a specific location. The process includes working with affected residents, businesses, schools, local police and fire departments, and others, to address their concerns. This public-involvement process may take a while, especially if the proposed countermeasures prove to be controversial and the types of traffic calming, and the locations within a neighborhood, may need to be modified based on public input.

The availability of funds to cover the costs of installation depends on local and state funding cycles. Some projects may cost only a few thousand dollars per location.

Effectiveness*

Pedestrians benefit from traffic calming because motorists are traveling more slowly and with a greater expectancy of the presence of pedestrians and therefore have more time to react to their presence. This means potentially less risk of a crash, fewer and less-severe conflicts, and greater perceived safety for the pedestrian. Raised intersections and curb extensions also improve sight distances between pedestrians and motorists.

The Australian "wombat" crossing usually consists of a raised crosswalk and bulbouts. Wombat crossings have generally reduced 85th-percentile vehicle speeds by about 40%.

At an intersection in Massachusetts, the rate of motorists who yielded to pedestrians increased from 10% to 55% after a raised intersection was installed.

* More information and references are available in the related strategy in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy

For more information and references, refer to the following strategy in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 10: *A Guide for Reducing Collisions Involving Pedestrians* — Strategy 9.1 C3

IV.4B) Provide Segment Traffic Calming Measures (P & T)

Strategy Overview

Traffic-calming encompasses a series of physical treatments meant to lower vehicle speeds and volumes by creating the visual impression that certain streets are not intended for high-speed or "cut-through" traffic. Thus, traffic calming may improve conditions for pedestrians. Traffic calming measures reduce the speed of motor-vehicle traffic, making drivers aware of the presence and priority of pedestrian traffic, and reducing cut-through traffic.

Enhancements

- Lane narrowing.
- Curvilinear streets.
- Chicanes.
- Chokers.
- Speed tables.

Traffic-calming treatments should be designed and applied under appropriate conditions, to maximize their effectiveness.

Information on U.S. experiences with various traffic-calming treatments can be found in ITE's *Traffic Calming: State of the Practice* (1999).

Targeted Crashes - Patterns

- Vehicle-pedestrian collisions at mid-block crossings and at nearby intersections.

Recommended Areas for Application

Rural

☐ Arterial
☐ Collector
☐ Local

Urban

☐ Arterial
☒ Collector
☒ Local

Implementation Time & Issues, Costs, and Associated Needs

It may take one year or more to implement some of these countermeasures. This time includes engineering studies and deliberations and discussions with all stakeholders. Design and construction of such measures can take place within a short timeframe as long as no additional right-of-way is needed. Speed humps or speed tables may be installed rather quickly, if consensus amongst residents exists. For example, in Glendale, Arizona, speed humps are typically placed within 30 days, following receipt of a signed petition showing consensus. The speed of installation, coupled with their relatively low cost, has made them the most popular type of traffic-calming treatment requested.

The availability of funds to cover the costs of installation depends upon local and state funding cycles. Some projects may cost only a few thousand dollars per location.

Effectiveness*

Curb Extensions or Bulbouts: Anne Arundel County, Maryland, has used a combination of medians and bulbouts near intersections. The medians narrow the traveled way and provide a sheltered storage area, while the bulbouts force drivers to make a lateral deflection as they enter the narrowed area. Medians with lateral deflection reduced the 85th-percentile speeds by 2 to 5 miles/hr (Walter, 1995).

In Ontario, Canada, Macbeth (1995) reported speed reductions on five raised and narrowed intersections and seven midblock bulbouts, in conjunction with lowering the speed limit to 30 km/hr. The proportion of motorists who exceeded 30 km/hr was 86% before the devices were built, but only 20% afterwards.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy

For more information and references, refer to the following strategy in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 10: *A Guide for Reducing Collisions Involving Pedestrians* — Strategy 9.1 C2

IV.5) Install or Upgrade Traffic and Pedestrian Signals (P,T,E)

Strategy Overview

Reduce vehicle-pedestrian crashes at signalized intersections or at midblock locations, where a significant volume of through or turning vehicular traffic is present.

Nearly 1/3 of all pedestrian-related crashes occur at or within 50 feet of an intersection. Of these, 30% involve a turning vehicle, whereas another 22% involve a pedestrian either running across the intersection or darting in front of a vehicle whose view was blocked just prior to the impact. Another 16% of these intersection-related crashes occur because of driver violation (for example, failure to yield the right of way).

Enhancements

- Pedestrian signs, signals, and markings
- Countdown pedestrian signal indications
- Lights in crosswalks in school zones
- Pedestrian-only phase or pedestrian-lead phase during signal operation
- Prohibition of right turn on red
- Public information or signs that educate pedestrians regarding use of push buttons
- Technology to show a push button is working

Targeted Crashes – Patterns

- Vehicle-pedestrian crashes.

Recommended Areas for Application

Rural		Urban	
☐	Arterial	☒	Arterial
☐	Collector	☒	Collector
☐	Local	☐	Local

Implementation Time & Issues, Costs, and Associated Needs

It may take more than a year to implement some of these countermeasures. Traffic engineers often conduct engineering studies to determine whether one or more of these countermeasures are warranted at a specific location. The availability of funds to cover the costs of hardware, signs, installation, and maintenance depends on local and state funding cycles. Innovative countermeasures such as automated detectors may require some additional time for adjustments to improve operations.

Costs associated with this strategy will vary widely, depending upon the countermeasure to be implemented and the conditions at the site.

Effectiveness*

Providing pedestrian push buttons may facilitate safe pedestrian roadway crossings at signalized intersections (vs. midblock crossings), where pedestrian conflicts with motor vehicles can be managed through use of pedestrian crossing signals and/or exclusive pedestrian-only phases during the signal operation. However, pedestrian push buttons at an intersection are often obscured by roadside furniture or other items. Providing visible signs alerting pedestrians to the presence of push buttons and anticipated wait time for the crossing signal may increase the use of existing pedestrian push buttons.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategy

For more information and references, refer to the following strategy in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 10: *A Guide for Reducing Collisions Involving Pedestrians* — Strategy 17.2 A6

IV.6) Improve Intersection Geometry (T)

Strategy Overview

Improve intersection geometry to aid pedestrians in crossing the street and reduce car-pedestrian crashes.

Enhancements

- Build raised pedestrian refuge islands, or medians at crossing locations, reduce exposure between pedestrians and motor vehicles, provide pedestrians more secure places during the street crossing, and simplify the crossing maneuver by creating the equivalent of two narrower one-way streets.
- Provide crosswalk enhancements, including striping patterns that increase conspicuity; additional, larger, lighted or overhead crosswalk warning signs; and flashing beacons on crosswalk signs activated by pedestrian push buttons.
- Install crosswalk lighting (in pavement or overhead) to increase nighttime visibility of pedestrians.

This strategy is intended for pedestrian crossings typically in urban and suburban settings and can be used at signalized or unsignalized intersections.

Targeted Crashes – Patterns

- Car-pedestrian crashes when pedestrians are attempting to cross multi-lane arterial or collector streets.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☐ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

Implementation time may be affected by the amount of public involvement and controversy surrounding the proposed strategy or program. This can occur during the planning, design, and funding acquisition processes. Crosswalk enhancements and lighting may only need several months to implement.

The cost for pedestrian refuge islands and raised medians will vary widely, depending upon the design, site conditions, and use of landscaping and whether the median can be added as part of another street construction project. Many crosswalk enhancement, signing improvements, and lighting are often considered low cost projects.

Effectiveness*

The FHWA (Federal Highway Administration, 2002) found that the presence of a raised median (or raised crossing island) was associated with a significantly lower pedestrian crash rate at multi-lane crossing locations, with both marked and unmarked crosswalks. In contrast, painted (not raised) medians and center two-way left-turn lanes did not offer significant safety benefits to pedestrians on multi-lane roads, compared to no median at all.

A comparison of undivided multi-lane roadways, two-way left turn lanes, and raised-curb medians showed that in both central business district and suburban locations, the pedestrian crash rate was significantly higher on undivided arterials than on arterials with raised medians.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 10: *A Guide for Reducing Collisions Involving Pedestrians* — Strategies 9.1 A3, B1, B2

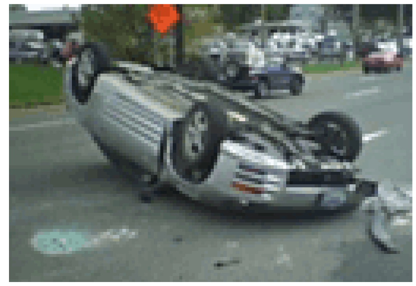
V.1) Implement Aggressive Driving Programs (T)

Strategy Overview

"Aggressive driving" can be defined as operating a motor vehicle in an impatient, pushy, and often unsafe manner that directly affects other drivers. In the U.S., the Surface Transportation Policy Project found that "aggressive driving "was a factor in about 56% of all fatal crashes."

Most law enforcement programs cited in NHTSA's *Aggressive Driving Enforcement: Strategies for Implementing Best Practices* were essentially examples of intensive traffic law enforcement. Traffic engineers should address traffic operation factors that apparently contribute to aggressive driving, such as poorly coordinated traffic signals. If judges imposed more severe sanctions for repeat aggressive driving offenders, the deterrent effect may be enhanced.

Research suggests that this type of effort is most likely to succeed when people that drive aggressively have a high expectation of being apprehended. To accomplish this, the intense enforcement efforts must support the public education campaign designed to target the aggressive driver.



Enhancements

- Public education and information campaign to reduce aggressive driving.
- Billboard message and radio advertisements during peak driving times to announce the increased enforcement efforts and encourage citizens to report aggressive drivers. Professionally designed public messages are recommended.
- Traffic law enforcement of all moving violations should be used to reinforce a public education and information campaign to reduce aggressive driving.

Targeted Crashes – Patterns

Aggressive drivers that put other drivers, and themselves, at a greater risk of collision, for example:

- Rear-end crashes.
- High-speed crashes.
- Rollover crashes.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

The implementation of this type of strategy requires the cooperation of a group of stakeholders, including law enforcement, traffic engineers and judges.

Costs are associated with paid radio announcements, billboards and other types of media outreach. Public service announcements may be used at little to no cost to the local agencies, however professionally developed messages are recommended. It is suggested that multiple forms of outreach be used to reach the aggressive drivers.

The intensive traffic law enforcement effort would likely require agencies to pay overtime expenses to increase the number of officers available for the effort. Studies suggest that by themselves, the effectiveness of public information and education programs on changing driver behavior is limited.

Effectiveness*

This strategy has been tried by multiple agencies and success has been reported. To date, there is limited published research to quantify the impact of this type of an effort on the reduction of aggressive driving.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies and Other Resources

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 1: *A Guide for Addressing Aggressive-Driving Conditions* – Strategies 4.1 A1, A2, A3

http://www.nhtsa.dot.gov/people/injury/enforce/aggressdrivers/aggenforce/index.html

"Aggressive Driving: Are you at risk?", p.1

V.2) Better Manage Vehicle Speeds (T)

Strategy Overview

Provide methods to better manage vehicle speeds along streets and highways. The National Highway Traffic Safety Administration advises that about 30% of all drivers killed in crashes were speeding. Increased demand for law enforcement services combined with limited law enforcement resources has made speed enforcement a challenge.

Enhancements

- Implement a speed management program. A successful speed management program requires the support of the community. If the community does not understand that speeding is a dangerous activity, they are likely to resist increased enforcement activities. An effective public awareness program can help the community to understand the need to reduce vehicle travel speeds.
- Install traffic calming techniques, like chokers or speed humps, and roadway designs to reduce the speed of vehicles at specific locations. Traffic and design engineers are also a vital partner in a speed management program. Traffic calming measures are not appropriate in all areas, and in many locations community support must be documented through surveys before these countermeasures would be employed.
- Enforce speed limits using law enforcement personnel and/or an automated speed enforcement program. Law enforcement personnel have several tools available to them to assist in the enforcement of speed violations. Radar, Lidar, and VASCAR equipment has been used successfully in the United States for years. Automated speed enforcement technologies have been more recently introduced in the United States. An automated speed enforcement program should be considered as part of an overall speed management program. Automated speed enforcement equipment is designed to be operated in a manned or unmanned mode using equipment on the side of a roadway. The equipment automatically measures the speed of vehicles passing by the equipment and takes photographs of vehicles exceeding a specified speed above the posted speed limit. When the equipment is attended by an individual, typically inside a van with the equipment, he/she verifies that the equipment is working properly. When the equipment is operating in an unattended mode, the system generally accommodates a secondary verification of the vehicle's speed. The automated system is a more efficient enforcement system that should be operated as part of a comprehensive strategy and it should not replace traditional law enforcement traffic stops.

Targeted Crashes – Patterns

Drivers that exceed the posted speed limits. At a higher speed, a driver has less time to react to a dangerous situation and is more likely to be injured should a crash occur.

- Injury crashes.
- Fatality crashes.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

The implementation of this type of strategy requires the cooperation of a group of stakeholders including law enforcement, traffic engineers and public awareness specialists.

Costs are associated with paid radio announcements, billboards, and other types of media outreach. Public service announcements may be used at little to no cost to the local agencies. It is suggested that multiple forms of outreach be used to help the community to understand the risks associated with driving too fast.

Traditional speed enforcement is labor intensive and would likely require agencies to pay overtime expenses to increase the number of officers available for the effort.

Automated speed enforcement programs typically require a legislative change to be utilized. In some parts of the country, these systems can be used today. In each situation, care should be taken to work with stakeholders to ensure the program is implemented in a manner that is acceptable to that community.

Effectiveness*

Recent studies of automated speed enforcement programs have shown that a 20% to 25% injury crash reduction is a reasonable expectation for conspicuous, fixed-camera automated speed enforcement programs.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Resources

Thomas, L.J., Srinivasan, R., Decina, L.E. and Staplin, L. (July 31, 2007), Safety effects of automated speed enforcement programs: A critical review of international literature accepted for presentation at the 2008 Transportation Research Board Annual Meeting.

Decina, L., Thomas, L., Srinivasan, R. and Staplin, L. *Automated Enforcement: A Compendium of Worldwide Evaluations and Results*. National Highway Traffic Safety Administration. July 2007.

V.3) Encourage Seat (Safety) Belt Use (P)

Strategy Overview

Motivate individuals that do not routinely use safety belts and encouraging vehicle occupants that occasionally refrain from wearing their safety belt to use a belt each time they ride in a vehicle. Seat belt use can reduce death and serious injury of front-seat occupants by nearly 50%. The use of seat belts is particularly important in high-speed crashes such as head-on crashes or lane-departure crashes on high-speed roads.

Enhancements

- Implement a highly visible and consistent enforcement is always a key to altering driver behavior and improving effectiveness of education programs.
- Implement an education campaign can take on many different forms, including: TV or radio ads, school visits, billboards, flyers, etc. Furthermore, the education campaign can be directed towards the general public or at target populations that have shown a reluctance to wear seat belts. Some examples of target populations include teenagers, pick-up truck drivers, males between 21 and 34, and some ethnic groups. This strategy may be applied by participating in statewide programs (such as "Click It or Ticket") or through creating a local program.

Targeted Crashes – Patterns

- Unbelted vehicle occupant fatalities that occur during a collision

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

Most State agencies have public information and education messages (print, TV, radio, billboards, etc.) that have already been developed. Also, agencies are likely already performing enforcement that could be expanded or enhanced. These factors will help reduce the time to implement a specially focused program. Likely the biggest hurdle to implementation is further growing the interest and number of law enforcement agencies that participate.

Costs of public education or enforcement campaigns will depend on the program implemented. The cost of messages delivered through school visits, print (such as pamphlets or billboards), radio ads, or TV ads have a wide range of costs. Additionally, the amount of enforcement used will directly impact the cost. An example cost for a statewide program would be approximately $500,000 per year. For a local agency, it could be significantly less.

Effectiveness*

The May 2005 "Click it or Ticket" program evaluation found that extensive public awareness combined with increased targeted seat belt enforcement in different locations had different results. This was the largest ever nationwide program to increase belt use. In some locations, seat belt use decreased by 2.4% while in others it was increased by 9.1%. While most locations experienced an increase in seat belt use, the largest percentage of seat belt utilization increase was experienced in locations with primary seat belt laws. The authors noted the May 2005 "Click It or Ticket" program had succeeded and seat belt use increased at locations where the combined extensive public awareness and increased occupant protection enforcement program was fully implemented.

Related *NCHRP Report 500* Strategies and Other Resources

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 11: *A Guide for Increasing Seat Belt Use* — Strategies 8.1 A1, A2

Evaluation of the May 2005 "Click It or Ticket" Mobilization to Increase Seat Belt Use, DOT HS 810 778

V.4) Reduce Driving Under the Influence (P)

Strategy Overview

Several strategies have been proven to reduce alcohol-impaired driving: 1) reducing the distribution of alcohol to impaired and underage persons and 2) deterring impaired driving.

Enhancements

- Reinforce responsible alcoholic beverage service policies by retailers to reduce the supply of alcoholic beverages to impaired individuals and under age. Training programs help retailers identify underage and intoxicated patrons. The training can help them to manage this situation and refuse to make a sale when it is not be appropriate. Compliance checks, using underage people working with a police department to attempt to buy alcoholic beverages, verify existing laws are being followed. By publicizing these efforts, more responsible beverage service is reinforced.
- Conduct regular, well publicized DUI checkpoints to reduce impaired driving. Regional coordination of enforcement efforts makes it possible to publicize checkpoints without creating an excessive burden on each individual agency. Encouraging law enforcement to make detection of drinking drivers a continuous focus assists the long-term enforcement success.
- Publicize and enforce zero tolerance laws for drivers under the legal drinking age. This policy has been proven to reduce alcohol-impaired driving by this high risk group. All states have laws prohibiting people under the age of 21 to operate a motor vehicle with alcohol in their system. Some states define this as having a blood alcohol content (BAC) of over 0.00% while other states prohibit a BAC over 0.02%.

Targeted Crashes – Patterns

- Alcohol-impaired crashes
- Driving under the influence (DUI)

Alcohol retailers that may sell beverages to underage or impaired people, underage persons that may drive after drinking an alcoholic beverage, and a driver that may choose to drive while impaired by alcohol.

Recommended Areas of Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

Some alcohol retailers resist server training until they learn that it may help reduce exposure to lawsuits. In locations where the training is mandated, the costs can be covered by the retail business or by individual servers. Training can be provided by state agencies or private companies. NHTSA has produced a guide for planning and publicizing DUI checkpoints that can assist agencies. Time is required to plan for a checkpoint and warning signs, traffic cones and lights are required for the operation. The largest cost for a checkpoint operation is the labor required for the police resources. NHTSA has encouraged the use of reduced staffing DUI checkpoints and several federal and state resources are available to cover some checkpoint costs.

Publicity is important to making these strategies successful and although many forms are not very costly, high-visibility publicity can have high costs. Handouts at new driver license offices could be used to explain the zero alcohol law for underage drivers would be one low cost publicity example.

Effectiveness*

Research suggests that server training can result in fewer patrons being impaired when they leave a licensed business thus reducing the risk of a later alcohol related crash. Studies have shown that well planned and publicized DUI checkpoints can reduce alcohol related crashes by 10% to 30%. A Maryland study found that publicizing a new zero alcohol tolerance policy for underage drivers resulted in a 51% drop in alcohol involved crashes with drivers under the age of 21.

* More information and references are available in the related strategies in the *NCHRP* Report500 series.

Related *NCHRP Report 500* Strategies and Other Resources

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume16: *A Guide for Reducing Alcohol-Related Collisions* – Strategies 5.1 A2, B1, B3

Responsible Beverage Service Information – http://www.tf.org/tf/alcohol/ariv/facts/factsh3.html

DUI Checkpoint Guide – http://www.nhtsa.dot.gov/people/injury/alcohol/saturation_patrols/SatPats2002.pdf

VI.1) Prepare Personnel to Provide First Aid on Roadways (T)

Strategy Overview

The rapid delivery of emergency medical care increases the probability of survival for many patients. Law enforcement personnel, highway maintenance personnel, and other state and local government personnel travel on the local roads on a regular basis. If these people are prepared to administer emergency medical care to a crash victim, the patient has an increased opportunity for survival.

Enhancements

- Provide personnel with first responder training and a first aid kit. Such measures will expand the number of people available to assist crash victims as needed. These people would be able to provide some assistance until an Emergency Medical Technician (EMT) or paramedic arrives at the scene.

These personnel should have access to some basic first aid equipment to assist at a crash scene. A first aid kit should include items such as gloves, a CPR mask, emergency blankets, and trauma pads. Most highway incidents that require first aid are the result of crashes causing traumatic injuries. Some of these traumatic events lead to or are caused by cardiac events; therefore, agencies should consider providing an Automatic External Defibrillator (AED).

If these personnel were also provided cellular telephones, they would be able to ensure that more highly trained Emergency Medical Services (EMS) personnel were dispatched to the scene as soon as possible.

Targeted Crashes – Patterns

- Injury crashes.
- Crashes caused by a traumatic event.

Crash victims benefit from reduced time between injury and basic first aid.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

This strategy would require a partnership between agencies to expand the pool of EMS trained personnel. Costs would be associated with the initial training, ongoing continuing education and for first aid kits. Administrative costs may be involved to coordinate the program and evaluate the program effectiveness.

Effectiveness*

It is difficult to isolate the impact of an increased number of first responders on the injury severity of crash victims. No known studies have been conducted to quantify the expected benefit of this effort.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 15: A Guide for Enhancing Rural Emergency Medical Services – Strategies 20.1 A1, C4, C6, C7

VI.2) Reduce Emergency Medical Services response time to a crash (T)

Strategy Overview

Reduce the amount of time between the occurrence of an injury and the arrival of appropriate Emergency Medical Services (EMS) care in order to improve the chances of survival in an injury crash.

The proliferation of cellular telephones has decreased the amount of time it takes for a typical crash to be reported. On occasion, the crashes are reported at an inaccurate location. As a result, EMS personnel may be sent to the wrong location and a delay in response to the actual location occurs.

Enhancements

- Implement Public Safety Answering Point service for cell phone callers. The technology exists to locate the cellular telephone caller through the Public Safety Answering Point (PSAP) that they access by calling 911. If the PSAP is compliant with the FCC wireless “Phase II” automated location capability, the PSAP can determine the location of the caller.
- Improve number and/or type of milepost markers for more accurate location.

Targeted Crashes – Patterns

- Injury crashes.
- Crashes caused by traumatic event (cardiac arrest, etc.).

Crash victims benefit from reduced time between injury and the arrival of EMS personnel.

Recommended Areas for Application

Rural
- ☒ Arterial
- ☒ Collector
- ☒ Local

Urban
- ☐ Arterial
- ☐ Collector
- ☐ Local

Implementation Time & Issues, Costs, and Associated Needs

The implementation challenge for this type of strategy is primarily financial. The cellular telephone and telecommunication equipment industries can build this type of system in one to two years, if the costs can be paid. Local agencies may want to partner with state 911 offices to seek adequate funding for this project.

This system works in areas where adequate cellular telephone coverage exists. If adequate coverage does not exist, that challenge should be addressed first. Costs are associated with establishing the necessary data networks to transfer automatic number identifier (ANI) and automated location identification (ALI) information. The PSAP would need Phase II-compliant 911 telephone termination equipment and accurate maps. The associated training costs would be minor in comparison with the capital costs involved in establishing the system.

Effectiveness*

The safety benefit of expanded cell phone coverage has not been thoroughly studied; however, it has been noted that more than half of all 911 calls are made using cell phones in some jurisdiction. Therefore, expanded and improved (such as FCC wireless “Phase II” automated location capability compliant) can be expected to improve EMS notification and response times.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series:

NCHRP Report 500, Volume 15: A Guide for Enhancing Rural Emergency Medical Services – Strategies 20.1 D1, D2

VI.3) Educate Road Workers to Manage Incidents (T)

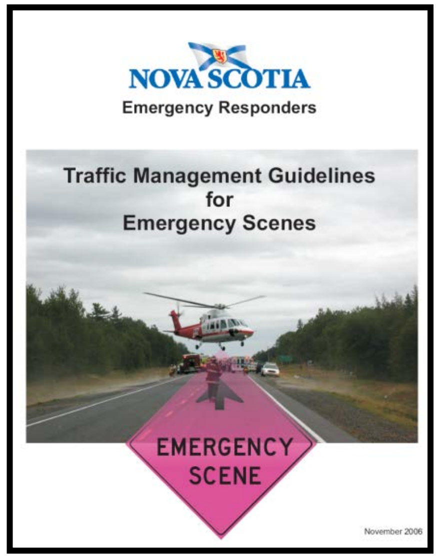
Strategy Overview

Secondary crashes at a crash site after emergency response has arrived at the scene are often preventable. The underlying cause of secondary crashes can vary, but the common accepted reason is inattention or speeding by passing motorists. Allow emergency responders to keep their focus on injured persons by aiding them with traffic management.

Enhancements

- Educate and equip roadway maintenance personnel and highway helpers to respond to crash sites for the task of establishing, marking and signing buffer zones.
- Create buffer zones that include advance warning and are highly visible. This is a preferred technique to increase approaching motorists' awareness of the situation ahead.

Today, emergency responders are often responsible for establishing their own buffer zones. However, the focus of these individuals is often on care for the injured persons and not on traffic management.



Targeted Crashes – Patterns

Prevent or reduce the severity of secondary crashes that happen once emergency medical services are on site. Not only can this protect emergency responders, but will protect vehicle occupants that were involved in the secondary accidents.

Recommended Areas for Application

Rural	Urban
☒ Arterial	☒ Arterial
☒ Collector	☒ Collector
☒ Local	☒ Local

Implementation Time & Issues, Costs, and Associated Needs

Maintenance workers and highway helpers often receive some traffic management training, so it is expected that the cost and time to implement will be relatively small. Furthermore, roadway agencies will likely have equipment needed, but it will need to be staged in a location or vehicle so that it can be quickly transported to a crash site.

Coordination is needed between the roadway agency and emergency response agencies to develop guidelines for when assistance is called for. Especially if crashes happen at night when maintenance workers are often not working in rural and small urban communities. Responses outside of normal working hours will likely be the largest cost for highway agencies since this will likely require paying for overtime.

Effectiveness*

No known formal studies of this sort of program have been completed. However, it is expected that secondary crashes, especially those involving emergency responders and their vehicles can be reduced.

Example traffic management training programs that were developed for emergency responders is available at http://www.respondersafety.com/.

* More information and references are available in the related strategies in the *NCHRP Report 500* series.

Related *NCHRP Report 500* Strategies

For more information and references, refer to the following strategies in the *NCHRP Report 500* series.

Objective VII. Innovative Safety Techniques

New and innovative highway safety techniques continue to be developed. The focus of this guide is to outline strategies for local agencies that are proven and tried by agencies. This section outlines newer strategies that are now being used and tested in the United States that show promise particularly for local agency use.

T1) Targeted Education of High Crash Locations

Awareness by drivers of local safety issues is an important component to assist drivers in their task of safe driving. While safe driving practices are important in all situations, this can be especially important at locations with a history of a high number of total or severe crashes. These locations may be an entire corridor or a specific curve or intersection. Safety awareness education could be done in a variety of forms, but one approach is posting warning signs informing drivers that the corridor or location is part of an accident reduction program. In addition, other educational methods might be used to target local residents, including direct mailings, web pages, community presentations, etc (refer to examples in Section V, Improve Enforcement and Education Programs).

As part of an education program, agencies should provide drivers with proactive information about crash avoidance strategies (for example, slow down, buckle up, take extra care when officers are have a vehicle stopped on the roadside, take care when passing, etc.). For example, an unsignalized intersection could have a left-turn yield crash pattern, or a signalized intersection might have a history red-light running crashes. Posting a sign advising the site is a crash reduction location with a simple related message may be useful for drivers. Another example of targeted education and the designation of an accident reduction corridor is for a site with a head-on passing related crash history.

T2) Local 4E Fatal Crash Debriefings

Several jurisdictions across the country have established a formal multidisciplinary fatal crash debriefing process. The concept is to have a group of traffic safety officials from different perspectives view fatal crashes in a structured manner. The result of the review is to identify what actions might be taken to reduce the chances that this type of crash might occur again in the future.

The fatal crash debriefing process for Otter Tail County, Minnesota, is an example. The State of Minnesota established a Safe Community Grant program that required a Fatality Review Committee (FRC) to be a part of each grant recipient's program (refer to the Fatal Review Committee Tip Sheet in Attachment C, Examples of Local Agency Safety Efforts.

In Otter Tail County, the County Public Health Department established the FRC and is the lead for the review process. Every fatal crash in the County is reviewed by the group that includes the Otter Tail County Sheriff's Office, the Minnesota State Patrol, traffic engineers, emergency medical services personnel, and public information specialists. Typically, three to four fatal crashes are reviewed at each of the periodic committee meetings. The investigating law enforcement agency presents crash investigation information to the group including photographs of the crash scene. Each crash review takes approximately 30 to 40 minutes and the objective is to improve the understanding of the circumstances related to the crash.

For example, for emergency medical services (EMS) related strategies, the crash reviews have provided ideas about how to improve EMS response times and a better information as to when a helicopter should be utilized for medical evacuation. In circumstances such as a fatal crash, the Committee has noted that the general public often felt that road defects were a significant contributing factor to a fatal crash. Typically, a detailed crash review indicated this was usually not accurate. Instead, the Committee found in many instances, alcohol-related crashes and a lack of seat belt use are major factors in fatal crashes. The public education professionals are able to incorporate these findings into outreach programs and alcohol-server training programs.

T3) Educate Maintenance Workers to Improve Safety

Especially for rural locations, single-vehicle run-off the road crashes may involve a collision with a fixed object. Many fixed-object collisions involve an object that can not be easily removed or relocated (utility poles, tree on private property, culvert headwall, etc.), but some involve an object that might be addressed by maintenance personnel, for example, trees growing in the right of way. Educating maintenance workers to identify and report possible fixed objects that need to be mitigated as part of maintenance efforts (see Strategies in Objective III) is a first step in providing an improved safer roadside. Maintenance workers often spend the most time on the road and have the most frequent opportunity to view these issues. Maintenance workers might also become active in reporting other situations that might be a safety issue, such as pavement edge drop-offs, pavement locations that may periodically ice over, and features that may limit intersection sight distance.

While using maintenance workers are the focus of this strategy, local agencies should consider educating office staff to identify and report safety issues. This education and reporting could be expanded to other local public agencies (such as, law enforcement, park staff, etc.).

In creating such a program, consideration should be given to developing a simple form to allow easy reporting and locating of safety concerns, a defined procedure for responding, and a follow up communicating back to the person submitting the request if any action was taken and why.

T4) Provide Bus Stop Locations with Accessible Sidewalks, Crosswalks, etc.

The initial and final links of any transit system are the pedestrian links to the home, place of work, or other activity center. Without safe and comfortable pedestrian links, transit is not attractive to many users. The bus stop serves as the first point of entry to the bus transit system; therefore, the bus stop should be safe and customer friendly to encourage the continued use of the service. Bus stop location, spacing and design are critical elements in the quality of bus service.

The Americans with Disabilities Act of 1990 (ADA) mandates that a loading pad at least 5 feet wide by 8 feet long be provided at all new bus stops. These are the minimum dimensions needed to deploy a lift or ramp and allow a customer in a wheelchair to board or alight from the vehicle. The pad must be stable, firm, and slip-resistant, and connected to the curb. In addition, any new and relocated stops must include a landing area that meets or exceeds these standards

The presence of sidewalks on both sides of the street has been found to significantly reduce pedestrian crash risk (see Strategy IV.1), compared to locations where no sidewalks or walkways exist. Because bus stops are often high pedestrian volume areas, the installation of sidewalk may reduce pedestrian injuries and fatalities at bus stop locations.

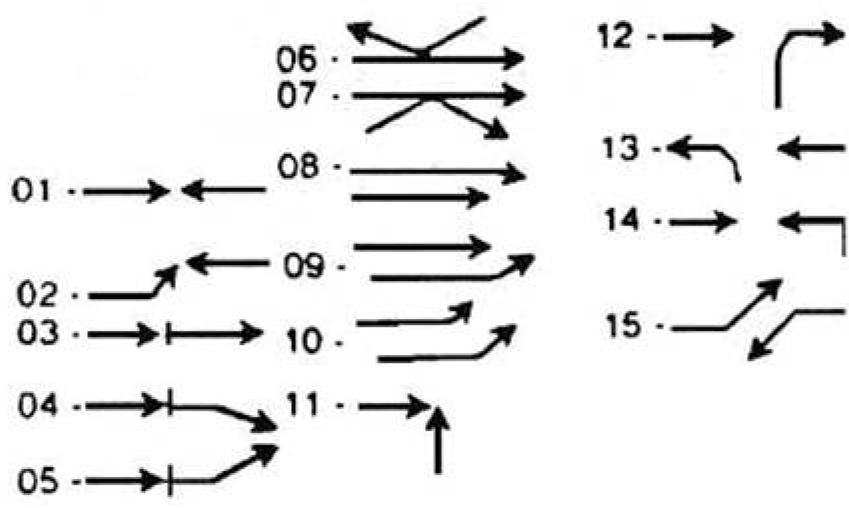
T5) Implement Quick Law Enforcement Crash Data Reporting

Good data about crash experience helps to identify opportunities for safety improvement. Unfortunately, many law enforcement agencies have progressively completed full investigative reports for a smaller percentage of crashes reported. Citing many competing demands on their personnel, some agencies, for example, have stopped completing investigative reports in property damage only crashes where the vehicles involved in the crash could be driven away from the scene.

Recognizing that a complete crash investigation report in every situation would be ideal for safety analysis but impractical from a manpower resource standpoint, agencies have sought alternatives to gather useful data in an efficient manner. The Howard County Police Department in Maryland established a policy to gather simple crash type data in cases where no police report was required. Whenever an officer in Howard County is dispatched to a reported collision, an incident report number is initiated in the Computer Aided Dispatch (CAD) system. In some situations, the officer will complete an investigative report based on the crash and the CAD system is updated to show that a written report is available. In many cases, an investigative report is not required. In these situations, the officer indicates for the CAD system that the incident is verified as a collision, there will be no written report and the crash type is described by using one of the following codes:

Exhibit B-1 illustrates crash types used by the Howard County (Maryland) Police Department in situations where no investigative report is required by policy. These codes match the type of collision data in the Maryland Automated Accident Reporting System.

EXHIBIT B-1
Quick Reporting Crash Types Used by Howard County (Maryland) Police Department



16. Collision with a deer

17. Single Vehicle

88. Private Property

The officer's brief radio transmission of "10-8, NR, 01" indicates to the dispatch center that the officer verified a collision at the location where the officer had been dispatched, that the officer is back in service, no report would be completed, and this was a head-on collision. When the call is closed by the dispatcher, the code of "NR, 01" is entered into the CAD database. The effort involved in adding the collision type to the existing CAD database is minimal.

This crash data is searchable by location and by type. In Howard County, state and local traffic engineers are provided this data on a monthly basis or in response to a specific request. The public works engineer or traffic engineer is able to review the crash history at each location based on the complete investigative reports and other verified crashes. Since the Howard County code is the same as the investigative report code for type of collision, the engineer is able to obtain a more accurate view of the scope of the history.

Another method to increase the crash data available for future analysis attempts to increase the number of crashes reported to law enforcement. Agencies have permitted individuals to report a crash by telephone after they have departed from the crash scene. In some cases, agencies have accepted web based self reporting of crashes. In each situation the number of crashes in the database tends to increase. While questions exist about the accuracy of self reported crash data, there is limited evaluation data available at this time.

References

Howard County Department of Police, General Order ADM-11, *Departmental Reporting System*

Howard County Department of Police, General Order OPS-47, *Radio Communications*

ATTACHMENT C

Example of Local Agency Safety Efforts

THIS PAGE INTENTIONALLY LEFT BLANK.

Otter Tail County, Minnesota – Fatal Review Committee Tip Sheet

Description

Each Safe Community TZD Coalition must establish a Fatality Review Committee (FRC) to review each fatal crash that occurred in their area. The Committee must include, at a minimum, representatives from law enforcement, county and district state traffic engineers, health, education, and the Safe Community Coordinator. The FRC will review each fatal crash, looking at the elements which include who, what, where, when, and why the fatality occurred and to determine if certain trends or patterns can be identified from the review. The FRC will make recommendations to the coalition on how this fatal crash could have been avoided and report any trends or patterns. The FRC must meet no later than 30 days after the data from a fatal crash is available. The reviews of the fatal crashes will be included in the quarterly reports submitted to the OTS. (The purpose of this committee is to identify any trends that can be addressed to prevent similar types of crashes from occurring.)

1. Develop a partnership with area Law Enforcement (local police department, county sheriff department, and State Patrol) to help assist in identifying area fatalities, obtaining accident reports, and attending the Fatal Reviews. It is important to establish this partnership prior to a fatal crash and discuss the issue of data privacy. The crash reports from law enforcement become a public document after an investigation is closed, therefore anyone may view them.

2. Consider holding Fatal Reviews apart from your regularly scheduled Safe Communities Coalition Meetings. The FRC may include some members from your Coalition but also those who are not a part of it. Holding a separate meeting also gives the FRC a higher priority as a special meeting.

3. Invite all agencies that responded to the actual fatal crash. Ideally you will have the actual people who responded to the crash. If this is not possible, it is important to have another representative attend from the responding agency. Along with the representatives listed above, you may want to include Ambulance, Medical Services, Fire Department, County/City Attorney, First Responders, and government officials.

4. It may be helpful to use a form or spreadsheet to record the specifics of the crash and the analysis of the members of the FRC. These forms may be useful for your Quarterly Reports to the Office of Traffic Safety also. Templates of these forms are available. Assign a member to be the recorder during the meeting.

5. It is imperative that you have an actual copy of the accident/investigation report from Law Enforcement at the FRC. This will ensure you have the correct data and not just hearsay. Likewise it is important that all members return the reports to law enforcement at the conclusion of the FRC.

6. The Coordinator of the FRC should be sure that all members present have a chance to voice their insight into the crash. All responding agencies will have a different perspective on the crash details. This is what contributes to a successful Fatal Review.
7. Allow for approximately 45 minutes to review each fatal crash. It is important to review the crash in depth to find those contributing factors (usually human behaviors) that could have been prevented the crash.
8. Have the group identify the contributing factors of the crash and then make recommendations on how a similar crash may be prevented in the future. Be especially sensitive to whether the crash victim(s) were using seat belts and if alcohol, speed, or distractions were contributing factors.
9. Develop key messages to put out to the public in the form of a newspaper article, letter to the editor, radio public service announcement, or other similar venue.
10. Do not invite family members or those close to the victims of the fatal crash. The intent of the FRC is to go over the facts of the crash and may be very upsetting for those close to the victims.

Page 2 of 2

EXHIBIT C-1
Example Fatal Review from Otter Tail County, Minnesota

OTTER TAIL COUNTY

MOTOR VEHICLE FATAL REVIEW

CASE #:

DEMOGRAPHICS:

DATE	TIME	WEATHER CONDITIONS	ROAD CONDITIONS	LOCATION	RESPONDING AGENCIES

	MAKE	MODEL	VEHICLE YEAR	POSSIBLE CONTRIBUTING FACTORS:
VEHICLE A:				
VEHICLE B:				

OCCUPANTS:	AGE	SEX	CHEMICAL USE	MEDICAL CONDITION	LAP BELT USE	SHOULDER BELT USE	CHILD SEAT	EJECTED	HEALTH STATUS	AIR BAG
DRIVER A:										
FRONT PASSENGER A:										
REAR PASSENGER A1:										
REAR PASSENGER A2:										
DRIVER B:										
FRONT PASSENGER B:										
REAR PASSENGER B1:										
REAR PASSENGER B2:										

EDUCATION NOTES & ACTION PLAN INCIDENT:

EMERGENCY MEDICAL SERVICES NOTES & ACTION PLAN FOR INCIDENT:

LAW ENFORCEMENT NOTES & ACTION PLAN FOR INCIDENT:

ENGINEERING NOTES & ACTION PLAN FOR INCIDENT:

OTHER NOTES & ACTION PLAN FOR INCIDENT: