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Employ Multiphase Signal Operation

WHERE TO USE

Signalized intersections with a high frequency of angle crashes involving left turning and opposing through vehicles. A properly timed protected left-turn phase can also help reduce rear-end and sideswipe crashes between left-turning vehicles and the through vehicles behind them.

Photos by: Texas Transportation Institute, FHWA

DETAILS

This strategy includes using protected left-turn phases and split phases. A two-phase signal is the simplest method for operating a traffic signal, but multiple phases could improve safety. Left turns are widely recognized as the highest-risk movements at signalized intersections. Protected left-turn phases significantly improve the safety for left-turn maneuvers by removing conflicts with the left turn. Split phasing, which provides individual phases for opposing approaches, could improve intersection safety but increases the overall delay and should be used cautiously.

KEY TO SUCCESS

The overall length of the turn lane is a key element in the design of the lane. A lane that does not provide enough deceleration length and storage space for left-turning traffic could cause the turn queue to back up into the adjacent through lane. This can contribute to rear-end and sideswipe crashes and increase delay for through vehicles.

ISSUES

A separate phase for the left-turn movement may reduce delay for the vehicles turning left but could result in more overall delay. The length of signal phase and cycle length should be compatible with the left-turn lane length. Through-vehicle queues could block turn lanes that are too short, making the lane inaccessible and also negating the effectiveness of a lead left-turn phase. Provision of a left-turn lane on an approach may involve restricting left turns in and out of driveways. Implementation of improvements to signal phasing may necessitate the replacement of older controllers.

TIME FRAME ●○○

Implementing this strategy may range from a few months to three or four years. Protected-only phasing can be implemented only where a separate left-turn lane exists. Where the intersection channelization already exists, the cost can be very small. Even where no such channelization exists, it could be possible to re-stripe an approach to provide it.

At other locations, lengthening the left-turn lane, widening the roadway, acquiring additional right-of-way, or redesigning the roadway alignment may be needed in conjunction with changes in signal operation policies.

COSTS ●○○○

Costs could be highly variable and may depend on the condition and flexibility of the existing traffic signal and controller. If the existing traffic signal only requires a minor modification, then the cost would be low. If a completely new traffic signal is needed, then the cost could be higher. In addition to the equipment costs needed for the signal, expenditures are needed for advance warning signs and markings. Similarly, costs would be higher if additional dedicated left-turn lanes are required; these costs may include right-of-way, pavement, pavement markings, and lane use signs.

EFFECTIVENESS

TRIED/PROVEN: Various studies have proven that installing protected left-turn phases improves left-turn safety. The isolation of left-turning traffic usually reduces rear-end, angle, and sideswipe crashes, and improves the flow of through traffic. A protected/permitted left-turn phase has not been shown to provide the higher degree of safety of a protected-only phase, but it is safer than permitted-only phasing.

The Federal Highway Administration's *Signalized Intersections: Informational Guide* provides a summary of studies of the effectiveness of adding left-turn lanes and protected left-turn phases, and concludes that providing both a left-turn phase and left-turn lane appears to provide the most safety benefit. A Florida study concluded installing a protected left-turn phase can reduce all crashes 27-36% and left-turn crashes 41-48%, depending on traffic volumes. An ITE study indicates that employing split phasing can reduce crashes by 25%. Another study showed a 17% reduction in left-turn crashes with the use of a protected/permissive left-turn phase.

COMPATIBILITY

This strategy can be used in conjunction with other strategies for improving safety at signalized intersections, most notably strategies concerning the addition of left-turn lanes.

SUPPLEMENTAL INFORMATION

Highway agencies should review their traffic engineering and design policies regarding the use of, or warrants for, protected left-turn phases to ensure that appropriate safety-based action is being taken on routine projects. *NCHRP Synthesis 225: Left-Turn Treatments at Intersections* summarizes recent guidance on determining left-turn phasing.

For more details on this and other countermeasures: http://safety.transportation.org

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Optimize Clearance Intervals

WHERE TO USE

Signalized intersections with a high frequency of crashes related to clearance interval lengths that are possibly too short. These crashes include angle crashes between vehicles continuing through the intersection after one phase has ended and the vehicles entering the intersection on the following phase. Rear-end crashes may also be a symptom of short clearance intervals.

Photo by: FHWA

DETAILS

Clearance intervals provide safe, orderly transitions in right-of-way assignment between conflicting streams of traffic. Clearance intervals always include a yellow change interval and, in most cases, an all-red clearance interval.

Clearance intervals are a function of operating speed, the width of the intersection area, lengths of vehicles, and driver operational parameters such as reaction, braking, and decision-making time. The Institute of Transportation Engineers (ITE) has developed an equation for determining the length of the clearance interval.

Clearance intervals that are too short in duration (compared to the ITE method) can contribute to rear-end crashes related to drivers stopping abruptly and right-angle crashes resulting from signal violations. One study showed clearance intervals shorter than those calculated using the ITE equation have higher rear-end and right-angle crash rates than intersections with timings that exceed the ITE value. In the extreme, a too short interval can result in drivers operating at the legal speed limit being forced to violate the red phase. Another study noted that short signal intervals are associated with vehicle conflicts and red-light running.

Establishment of a policy for determining clearance interval duration is necessary to provide consistency throughout a jurisdiction's system. Also, consideration should be given to other enforcement actions associated with potential red-light running.

KEY TO SUCCESS

Clearance intervals should not be long enough to encourage disrespect in drivers for the interval—thereby contributing to red-light running and even more severe crashes—or so short as to violate driver expectancy regarding the length of the interval, resulting in abrupt stops and possible rear-end crashes.

ISSUES

One study suggests that drivers often do not assume that longer clearance intervals at some locations will mean they will occur at all signalized intersections. Further research may be needed, however, to show that lengthening a clearance interval does not create general expectations among drivers. As clearance intervals are increased, cycle length and delay will usually increase. Thus, an intersection may become safer, but the increased level of delay may raise objections from the traveling public. Longer cycle lengths may also lessen a single progression scheme's effectiveness.

TIME FRAME ●○○

Implementation time is low for changing the length of a clearance interval. Engineering studies, development of retiming plans, and field implementation are required.

COSTS ●○○○

Costs for changing the length of a clearance interval will be low. The design of the new signal timing and the reprogramming of the signal should be the only costs.

EFFECTIVENESS

PROVEN: This strategy is proven effective in reducing multivehicle crashes at signalized intersections. A study of signalized intersections in two counties in New York found a 9% reduction in multivehicle and a 12% reduction in injury crashes at intersections where the duration of the yellow change intervals was lengthened to meet ITE recommendations. The same study showed a 37% reduction in crashes involving pedestrians or bicyclists. Another study showed an 18% decrease in all types of crashes when the clearance interval was increased. Yet another study indicated a 15% decrease in all crashes and a 30% decrease in right-angle crashes when the yellow change interval was increased.

COMPATIBILITY

Optimizing the length of the clearance interval is compatible with other safety improvement strategies. Note that some strategies, including widening an approach to add left-turn lanes, may increase required clearance intervals. An alternative to clearance interval optimization is implementation of measures to reduce speeds on one or more approaches.

SUPPLEMENTAL INFORMATION

A detailed discussion on yellow and all-red intervals is provided in *Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running* (available from: http://safety.fhwa.dot.gov/intersections/).

For more details on this and other countermeasures: http://safety.transportation.org

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Restrict or Eliminate Turning Maneuvers (Including Right Turns on Red)

WHERE TO USE

Signalized intersections with a high frequency of crashes related to turning maneuvers. For right turn on red (RTOR), the target of this strategy is right-turning vehicles that are involved in rear-end or angle crashes with cross-street vehicles approaching from the left or vehicles turning left from the opposing approach, and crashes involving pedestrians.

Photos by: FHWA

DETAILS

Safety at some signalized intersections can be enhanced by restricting or prohibiting turning maneuvers. This strategy can be applied during certain periods of the day or by prohibiting particular turning movements altogether. This strategy may be appropriate where a turning movement is considered to be "high risk" and other strategies are impractical or not possible to implement.

Turn restrictions and prohibitions can be implemented by channelization or signing. However, signing alone will most likely require some periodic enforcement.

Prohibition of RTOR can help reduce crashes related to limited sight distance and pedestrians that involve right-turning vehicles. This strategy can also help reduce the frequency and severity of crashes between vehicles turning right on red and vehicles approaching from the left on the cross street or turning left from the opposing approach. This strategy can be implemented with signing although enforcement is often needed. Prohibition of RTOR at specific intersections can be implemented during certain times of the day. Supplemental sign plaques prohibiting RTOR when pedestrians are present have been used to help protect pedestrians.

KEY TO SUCCESS

One key to success is providing for safe and adequate alternative locations to make the turn in close proximity to the intersection where the prohibition is placed. A careful traffic engineering study should be made to ensure that the safety and operational problems calling for the prohibition are not merely relocated.

It will be important to include stakeholders in the planning and implementation of this strategy (e.g., law enforcement, property owners in the affected area, and transit agencies).

With respect to RTOR prohibition, a key to success is to establish that prohibition of RTOR is justified due to an existing pattern of right-turn collisions.

ISSUES

Prohibition of left turns at a major intersection may be difficult to justify unless the left-turn volumes are very low. It is generally preferred to more safely accommodate the turning movement at the point where the driver desires to turn than to displace the turn activity to an alternative location. Issues in implementing turn prohibitions become more complex at higher-volume suburban and urban signalized intersections. Drivers familiar with the intersection might fail to notice the prohibition of RTOR when the restriction is first put into place.

TIME FRAME ●○○

Implementation of the turn restriction or prohibition could vary from a few days to a few months, depending upon the extent of public information and education (PI&E) provided.

COSTS ●○○○

Costs may be variable. Turn restrictions can be implemented with low-cost signing, but enforcement of the regulation and PI&E campaigns regarding the new regulation will increase costs.

EFFECTIVENESS

TRIED: One study in Florida concluded that prohibiting left turns at intersections (signalized and unsignalized) can reduce all crashes by 45% and left turn crashes by 90%.

That same study determined that prohibiting right-turn-on-red can reduce right angle crashes by 30% and rear-end crashes by 20%.

COMPATIBILITY

This strategy can be used in conjunction with other strategies for improving safety at signalized intersections. Refer to *NCHRP Report 500: Volume 10* for a range of strategies aimed at pedestrian safety, many of which can work in concert with the implementation of turn restrictions, specifically RTOR prohibition.

SUPPLEMENTAL INFORMATION

When planning turn restrictions, it is important to include public transit agencies due to the potential effects on bus transit.

For more details on this and other countermeasures: http://safety.transportation.org

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Employ Signal Coordination

WHERE TO USE

Signalized intersections with a high frequency of crashes involving major street left-turning and minor street right-turning vehicles where adequate safe gaps in opposing traffic are not available. Major road rear-end crashes associated with speed changes can also be reduced by retiming signals to promote platooning.

Photo by: Texas Transportation Institute

This photo shows two closely-spaced intersections that are not coordinated. Poor coordination results in unnecessary stops, more delay, and possibly higher crash rates.

DETAILS

Signal coordination has long been recognized as having beneficial effects on the quality of traffic flow along a street or arterial. Good signal coordination can also generate measurable safety benefits, primarily in two ways.

Coordinated signals produce platoons of vehicles that can proceed without stopping at multiple intersections. Reducing the number and frequency of required stops and maintaining constant speeds for all vehicles reduce rear-end conflicts. In addition, signal coordination can improve the operation of turning movements. Drivers may have difficulty making permitted turning maneuvers because of a lack of gaps in through traffic. Crashes may occur when drivers become impatient and accept a gap that is smaller than needed. Such crashes could be reduced if longer gaps were made available.

Corridors with coordinated signals that experience a higher level of rear-end and angle crashes should be reviewed to determine if the timing should be revised or if the signals should be optimized again.

KEY TO SUCCESS

Signals up to a mile of each other should be coordinated. The grouping of the signals to be coordinated is a very important aspect of design of a progressive system. Factors that should be considered include geographic boundaries, volume/capacity ratios, and characteristics of traffic flow. Coordination across jurisdictional boundaries is strongly encouraged.

ISSUES

Signals too close together can present problems related to drivers focusing on a downstream signal and not noticing the signal they are approaching, or proceeding through a green signal and not being able to stop for a queue at an immediate downstream signal. Dispersion of platoons can occur if signals are spaced too far apart, resulting in inefficient use of the signal coordination.

Achieving a coordinated system along a corridor may be complicated by signal requirements associated with crossing facilities, any of which may also require signal coordination. The need for long signal cycles associated with multiphase operation and long clearance intervals will dictate the cycle length on which progression will be based. Such a cycle length may produce additional delays on crossing facilities.

Coordinating signals for an extended length of highway can involve multiple governmental jurisdictions. Agreement among the many governmental stakeholders must be achieved in such cases.

Along corridors heavily used by emergency services, implementation of signal preemption may be considered (see Signalized Fact Sheet A5). On some corridors heavily served by bus transit, transit priority systems may be considered. Other corridors may include at-grade rail crossings. In all three situations, preemption may break up a platoon or cause the system to get out of coordination for several cycles and negate the effectiveness of a coordination scheme.

TIME FRAME ●●○

Implementation time for signal coordination is short to moderate. Installation of signals that may otherwise be unwarranted will increase implementation time, due to additional approvals required. The type of signal system to be installed or upgraded will also affect implementation time.

COSTS ●○○○

Costs involved will be low to medium. If a new system is required to control the coordination, costs will be higher and will include design of the system and purchase and installation of new equipment.

EFFECTIVENESS

PROVEN: Studies have proven the effectiveness of signal coordination in improving safety. The Institute of Transportation Engineer's Traffic Safety Toolbox cites two studies of coordinated signals with intersection crash frequencies that dropped by 25 and 38%. One of the studies showed an improvement in crash rates for mid-block sections as well. Signal coordination can also contribute to a decrease in red-light running. An Arizona study on the effectiveness of traffic signal coordination concluded that crash rates on intersection approaches decreased 6.7% after signal coordination.

COMPATIBILITY

Traffic signal coordination is compatible with most other strategies to improve signalized intersection safety. Signalized Fact Sheet A7 discusses removing a signal that is no longer warranted. Consideration may be given to retaining an unwarranted signal to use in a coordinated system.

For more details on this and other countermeasures: http://safety.transportation.org

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Employ Emergency Vehicle Preemption

WHERE TO USE

Signalized intersections where normal traffic operations impede emergency vehicles and where traffic conditions create a potential for conflicts between emergency and non-emergency vehicles.

Photo by: Texas Transportation Institute

DETAILS

Signal preemption allows emergency vehicles to disrupt a normal signal cycle in order to proceed through the intersection more quickly and under safer conditions. The preemption systems can extend the green on an emergency vehicle's approach or replace the phases and timing for the whole cycle. The *Manual on Uniform Traffic Control Devices* discusses signal preemption, standards for the phases during preemption, and priorities for different vehicle types that might have preemption capabilities.

A signal preemption system can decrease emergency vehicle response times. Preemption is especially useful where emergency vehicles are likely to have to travel some distance along a corridor. Also, preemption can provide both a safety and operational benefit on high-speed roadways where emergency vehicles need to enter the intersection from the minor road.

Many systems have applications in transit-vehicle priority as well as signal preemption for emergency vehicles. Some jurisdictions use confirmation lights to inform drivers that emergency vehicles are preempting the signal or signs that inform drivers that a police pursuit is in progress.

KEY TO SUCCESS

One key to success is ensuring that the preemption system works when needed by providing clear sight lines between emergency vehicles and detectors. Also, it is important to ensure that vehicles from a variety of jurisdictions will be able to participate in the signal preemption program. The focus of the treatment should be on fire and emergency medical services because they often follow standard routes. Another key to success is the coordination of implementation across jurisdictions, including compatibility of equipment and technology, as well as operational policies.

ISSUES

Preempted signals that stop vehicles for too long may encourage disrespect in drivers for the red signal, and they may decide to proceed even though the signal is red.

Preemption of signals by emergency vehicles will temporarily disrupt traffic flow. Congestion may occur, or worsen, before traffic returns to normal operation. One study of signal preemption systems in the Washington, D.C., area demonstrated that once a signal was preempted, coordinated systems took anywhere from half a minute to seven minutes to recover to normal operation. During these peak periods in more congested areas, vehicles experienced significant delays.

Light-based detectors need a clear line of sight to the emitter on the vehicles. This line could become blocked by roadway geometry, vehicles, foliage, or precipitation.

TIME FRAME ●●○

Implementation time will vary from short to medium, based upon the number of intersections and number of agencies involved in the preemption system.

COSTS ●●○○

Costs for installation of a signal preemption system will vary from medium to high, based upon the number of signalized intersections at which preemption will be installed and the number of emergency vehicles to be outfitted with the technology. The number of detectors and the intricacy of the preemption system could increase costs.

EFFECTIVENESS

PROVEN: Installation of signal preemption systems for emergency vehicles has been shown to decrease response times. A review of signal preemption system deployments in the United States shows decreases in response times between 14 and 50% for systems in several cities. In addition, the study reports a 70% decrease in crashes with emergency vehicles in St. Paul, Minnesota, after the system was deployed (though the extent to which emergency vehicle priority was implemented in the city is unclear).

COMPATIBILITY

Signal preemption is compatible with most other strategies to improve signalized intersection safety.

SUPPLEMENTAL INFORMATION

Highway and other agencies should ensure that their policies for traffic signals include use of signal preemption systems. A successful program requires the coordinated and cooperative involvement of agencies from engineering, enforcement, emergency medical services, etc. throughout the area. Implementation of a preemption system should be considered as part of programs to upgrade corridor or jurisdictional traffic signal and control systems.

For more details on this and other countermeasures: http://safety.transportation.org

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Improve Operation of Pedestrian and Bicycle Facilities at Signalized Intersections

WHERE TO USE

Signalized intersections with high frequencies of pedestrian and/or bicycle crashes. Also on routes serving schools or other generators of pedestrian and bicycle traffic.

Photos by: Texas Transportation Institute, FHWA

B. This photo shows a example of using a no right-turn sign in conjunction with a leading pedestrian Phase. C. An example of a pedestrian countdown signal.

DETAILS

Nearly one-third of all pedestrian-related crashes occur at or within 50 feet of an intersection. At traffic signals, the biggest crash problem for pedestrians comes from drivers making a permissive left turn across the crosswalk with the walk signal. Thirty percent involve a turning vehicle and another 22% involve a pedestrian either running across the intersection or darting in front of a vehicle whose view was blocked just prior to impact. Another 16% of these intersection-related crashes occur because of driver violation (e.g., failure to yield the right-of-way).

Traffic control improvements that can be made to an intersection to increase pedestrian safety include the following:

- pedestrian signs, signals (including countdown signals), and markings;
- crossing guards for school children;
- lights in crosswalks in school zones;
- pedestrian-only phase or pedestrian-lead phase during signal operation;
- prohibition of right turn on red (RTOR);
- public information or signs that educate pedestrians regarding use of push buttons; and
- technology to show a push button is working

Providing pedestrian push buttons may facilitate safe pedestrian roadway crossings at signalized intersections (versus mid-block crossings), where pedestrian conflicts with motor vehicles can be managed through use of pedestrian crossing signals and/or exclusive pedestrian-only phases during signal operation. Ensure that pedestrian push buttons are easily accessible and are ADA

compliant. Strongly consider the use of assessable push buttons that provide visual, tactile and audible cues. For existing push buttons, interim improvements, such as signing and removal of roadside furniture, can make them more accessible. Consult the AASHTO *Guide for the Development of Bicycle Facilities* for information on bicycle safety. Traffic control improvements that can be made to an intersection to increase safety for bicyclists include "Bicyclist Dismount" signs at intersections and stop and "Bicyclist Dismount" signs at intersections with bike trails.

KEY TO SUCCESS

The key to success for this strategy is to get the appropriate agencies to look at pedestrian and bicycle facilities from a more systematic point of view. That is, rather than making improvements where problems occur, anticipate the needs of pedestrians and bicyclists during the design of other intersection improvements. Incorporate appropriate improvements in the design before problems occur. Involve groups representing pedestrians and bicyclists in the early stages of a program's development.

ISSUES

Proper maintenance of improved pedestrian and bicycle facilities is also necessary. For example, some issues—a missing or broken section of sidewalk or a construction zone that forces pedestrians to walk in a traffic lane—are often overlooked.

TIME FRAME ●○○

Pedestrian improvements can be completed quickly if no additional right-of-way is needed.

COSTS ●○○○

Costs for most of the described improvements should be low. Updated signal equipment may be required to employ some of the advanced signal techniques.

EFFECTIVENESS

TRIED/PROVEN: One study showed a 25% decrease in pedestrian-related crashes with the installation of pedestrian countdown signal heads. Another study indicated a 20% decrease in all types of crashes when pedestrian signals were installed. Yet another study determined that implementing a leading pedestrian interval may decrease pedestrian-related crashes by 5%.

COMPATIBILITY

Strategies to reduce pedestrian and bicycle crashes are compatible with most other strategies for improving safety at signalized intersections.

SUPPLEMENTAL INFORMATION

The AASHTO *Guide for the Development of Bicycle Facilities* should be consulted for information on bicycle safety. *NCHRP Report 500: Volume 10* comprehensively addresses pedestrian safety.

For more details on this and other countermeasures: http://safety.transportation.org

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Remove Unwarranted Signal

WHERE TO USE

Signalized intersections where the traffic volumes and safety record do not warrant a traffic signal.

Photo by: FHWA

DETAILS

Traffic signals can remedy many safety and operational problems at intersections. However, signals often can adversely affect intersections. It is possible that a signal may no longer be warranted due to changes in traffic conditions. Problems created by an unwarranted signal, such as excessive delay, increased rerouting of traffic to less-appropriate roads and intersections, higher crash rates, and disobedience of the traffic signal can be addressed by removing the signal if doing so would not create worse problems.

Studies should be performed when considering removing a signal. This study should identify the appropriate replacement traffic control devices and any sight distance restrictions that may not have been an issue while under signalized control.

Once the new traffic control has been installed, the signal heads should be set to flash or should be covered for a minimum of 90 days to draw driver, pedestrian, and bicyclist attention to the change in control. After this period, the signal can be removed if the data collected during the study period support removal of the signal. The poles and cables may remain in place, however, for up to a year while additional analysis continues.

KEY TO SUCCESS

Keys to success include determining the appropriate traffic control to be used after the removal of the signal and removing any sight distance restrictions through the intersection.

Pedestrian and bicycle movements through the intersection should be considered when determining traffic control, geometric changes, and signing improvements that will be made when the signal is removed.

Keeping the public informed about the traffic control removal study will also lead to the success of this strategy.

ISSUES

Right-angle crashes may increase after the signal is removed. Removal of the traffic signals could delay the flow of pedestrians and bicyclists through the intersection.

TIME FRAME ●○○

Implementation time can vary, depending upon the extent and nature of public involvement.

COSTS ●○○○

Since implementation of this strategy requires removing traffic signals and replacing them with signs, its cost would be low. Costs would be attributed to the equipment needed for signal removal and temporary traffic control while implementing the new traffic control method.

EFFECTIVENESS

PROVEN: Removal of an unwarranted signal will eliminate excessive delay and disobedience of the signal indicators at the targeted intersections if these conditions exist because the signal is no longer needed. Signal removal should also decrease the use of inappropriate routes used by drivers in an attempt to avoid the traffic control signals and decrease the frequency of collisions (especially rear-end collisions).

One study found a decrease in annual average crash frequency of greater than one crash per year when intersections are converted to all-way stop control.

In 2005, a study reported that removing unwarranted signals may result in a 24% decrease in all crashes, a 53% decrease in injury crashes, a 24% decrease in right-angle crashes, and a 29% decrease in rear-end crashes.

COMPATIBILITY

Removal of traffic signals is typically done when studies show that traffic patterns have changed significantly. This strategy is not usually associated with any other strategies.

SUPPLEMENTAL INFORMATION

Highway agencies should review their traffic engineering and design policies regarding the removal of traffic signals to ensure that appropriate action is being taken.

Policy guidance regarding the removal of traffic signals is discussed in the *Manual on Uniform Traffic Control Devices*. The *MUTCD* should be consulted if agency policy has not incorporated the information from the *MUTCD*.

For more details on this and other countermeasures: http://safety.transportation.org

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Provide or Improve Left-Turn Channelization

WHERE TO USE

Signalized intersections where crashes related to left-turn movements are an issue.

Photos by: FHWA

DETAILS

This strategy includes the following: providing left-turn lanes, lengthening left-turn lanes, providing positive offset for left-turn lanes, providing positive guidance with channelization, and delineating the turn path.

Left-turn lanes allow separation of left-turn and through-traffic streams, thus reducing the potential for rear-end collisions. Because they provide a sheltered location for drivers to wait for a gap in opposing traffic, left-turn lanes may encourage drivers to be more selective in choosing a gap to complete the left-turn maneuver. Provision of a left-turn lane also provides flexibility in designing a phasing plan.

The design of the left-turn lane is crucial to its effectiveness as either a safety or operational improvement strategy. In providing left-turn lanes, vehicles in opposing left-turn lanes may block the respective driver's view of approaching vehicles in the through lanes. This potential problem can be resolved by offsetting the left-turn lanes.

Design criteria for selecting an appropriate left-turn lane length are presented in the AASHTO *Policy on Geometric Design for Highways and Streets*, the *TRB Highway Capacity Manual*, *NCHRP Report 279*, *NCHRP Report 457*, and the policies of individual highway agencies.

KEY TO SUCCESS

Keys to success in implementing left-turn lanes include the appropriate design of all elements (length, width, taper). Another key to success with left-turn lanes is to incorporate other strategies such as protected-only phasing.

ISSUES

Potential difficulties in providing a left-turn lane where it currently does not exist are the cost and acquisition of space required for the additional lane and the need to relocate the signal heads and hardware. The use of shoulders and/or parking lanes may be considered, but potential adverse safety concerns, such as lack of a shoulder for emergency stops, should be addressed. In addition, it will be important to address concerns from business owners or other stakeholders concerned about loss of parking.

TIME FRAME ●●○

Improving or implementing left-turn lane treatments can range widely in time. Where no changes to existing pavement or no new construction is needed, implementation can take only weeks or months. Where redesign or restriping of approaches is performed, time may be longer depending on the need to reposition or change the location of traffic signal heads or other hardware and acquiring right-of-way.

COSTS ●●○○

Costs of implementing or improving the design of left-turn lanes can vary. Where reallocation of available width by restriping is all that is needed, the cost can be relatively low. Where redesign and widening or other construction is necessary, costs will be moderate. Costs may include upgrading and/or relocating traffic signals and other hardware. Left-turn lane improvements that require right-of-way acquisition or major reconstruction can be high-cost projects.

EFFECTIVENESS

TRIED/PROVEN: Recent research has demonstrated the substantive safety effect of providing left-turn lanes. The safety effectiveness varies with the location (rural versus urban), number of legs, type of traffic control, and number of approaches for which the lane is installed. One study indicated crashes can be reduced up to 15% for rural three-leg intersections and 33% for rural four-leg intersections. The same study concluded that crashes may be reduced up to 7% at urban three-leg intersections and up to 19% at urban four-leg intersections. Another study indicated that crashes may be reduced up to 58% when a left-turn lane and turn phase are added.

COMPATIBILITY

This strategy can be used in conjunction with the other strategies for improving safety at signalized intersections.

SUPPLEMENTAL INFORMATION

Highway and other agencies should ensure that their design polices for new or reconstructed intersections incorporate consideration of all aspects of left-turn lane design and operation. Highway agencies should review their policies for left-turn warrants and design to consider explicit safety, capacity, and traffic operation considerations. Highway agencies may also wish to revise their standard intersection design details to accommodate offset left-turn lane treatments as their standard approach.

For more details on this and other countermeasures: http://safety.transportation.org

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Provide or Improve Right-Turn Channelization

WHERE TO USE

Signalized intersections with a high frequency of rear-end collisions resulting from conflicts between: (1) vehicles turning right and following vehicles; and (2) vehicles turning right and through vehicles coming from the left on the cross street.

Photo by: Texas Transportation Institute

DETAILS

Right-turn lanes can minimize collisions between vehicles turning right and following vehicles, particularly on high-volume and high-speed major roads. A right-turn lane may be appropriate in situations where a high number of rear-end collisions on a particular approach occur.

Key issues addressed in design guides include entering taper, deceleration length, and storage length. Design criteria for selecting an appropriate right-turn lane length are presented in the AASHTO *Policy on Geometric Design for Highways and Streets*, the *Manual on Uniform Traffic Control Devices*, and the policies of individual highway agencies.

Installation of a right-turn lane can create other safety or operational problems. For example, vehicles in the right-turn lane of the through road may block the cross-street right-turning drivers' view of through traffic (especially if right turn on red is permitted on the cross street). Channelization of the right turn with a raised or painted island can provide larger turning radii and an area for pedestrian refuge. Design details of channelizing islands for turning roadways can be found in AASHTO's *Policy on Geometric Design for Highways and Streets*.

Where curbed islands are provided, they offer a refuge for pedestrians. Where pedestrians use right-turn triangular channelization islands, crossing paths should be clearly delineated. The island itself should be made as visible as possible to passing motorists.

Removing small channelizing islands may improve right-turn channelization. Often, these islands were installed in urban areas for signal pole placement. Right-turning drivers may not see this island when approaching the intersection and may stop suddenly, increasing the potential for rear-end collisions.

Lengthening a right-turn lane can help improve operations and safety by providing additional sheltered space for vehicles to decelerate or wait to turn. Providing longer entering tapers and deceleration lengths can reduce the potential for rear-end collisions.

KEY TO SUCCESS

Properly designing the right-turn lane is paramount. Visibility of channelizing islands is also very important. Islands can be difficult for drivers to see, especially at night and in inclement weather. Raised islands have proven more effective than flush-painted islands at reducing nighttime collisions.

ISSUES

Older drivers benefit from channelization that better indicates the proper use of intersection travel lanes. However, older drivers find that making a right turn without an acceleration lane on the crossing street is particularly difficult. Using curbed islands is discouraged on high-speed roads.

Right-turn lanes can reduce the safety of pedestrian crossings. Elderly and mobility-impaired pedestrians may have difficulty crossing intersections with large corner radii.

Other issues to consider when designing a right-turn lane include provision of clear sight triangles, potential conflicts between turning vehicles and cyclists proceeding through the intersection, and potential need to move the stop bar on the cross street. Transit stops may also need to be moved from the near side to the far side of an intersection due to possible conflicts.

TIME FRAME ●●○

Where no changes to existing pavement or no new construction is needed, implementation can take only weeks or months. Where redesign or restriping of approaches is performed, the need to reposition or change the location of traffic signal heads or other hardware may require more time.

COSTS ●●○○

Where reallocation of available width by restriping is all that is needed, costs can be relatively low. Where redesign and construction are necessary, costs will be moderate. Costs may include upgrading and/or relocating traffic signals and other hardware and right-of-way acquisition.

EFFECTIVENESS

PROVEN: One study has indicated that installing a right-turn lane on one approach to a signalized intersection can reduce crashes by 4% and by 8% on two approaches.

COMPATIBILITY

This strategy can be used in conjunction with the other strategies for improving safety at signalized intersections.

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Improve Geometry of Pedestrian and Bicycle Facilities

WHERE TO USE

Signalized intersections with high frequencies of pedestrian and/or bicycle crashes and on routes serving schools or other generators of pedestrian and bicycle traffic.

Photos by: City of Tuscon, TTI

DETAILS

The mix of travel modes at intersections, along with the vehicle-vehicle conflicts possible, can create safety and operational concerns for non-motorists.

Geometric or physical improvements that can be made to an intersection to increase pedestrian safety include the provision of the following:

- continuous sidewalks,
- signed and marked crosswalks,
- sidewalk set-backs,
- median refuge areas,
- pedestrian overpasses,
- intersection lighting,
- physical barriers to restrict pedestrian crossing maneuvers at higher-risk locations,
- relocation of transit stops from the near side to the far side of the intersection, and
- other traffic calming applications to reduce vehicle speeds or traffic volumes on intersection approaches.

Some of the problems facing bicyclists at intersections include high-traffic volumes and speeds and the lack of space for bikes. Possible improvement projects include the following:

- widening outside through lanes (or adding bike lanes),
- providing median refuge areas,
- providing independent crossing structures,
- upgrading storm drain grates with bicycle-safe designs, and
- implementing lighting.

KEY TO SUCCESS

A key to successful pedestrian and bicycle facilities is careful planning. The network of facilities should be well connected to meet the needs of the community.

Landscaped medians should not obstruct visibility between pedestrians and bicyclists and approaching motorists or include objects representing a collision hazard to vehicles that may run onto the median.

ISSUES

Agencies must overcome decades of street and road construction projects that may have routinely ignored the need of pedestrians and bicyclists. Pro-pedestrian and bicyclist policies and construction programs need to be implemented to correct this problem. Refuge islands may conflict with the need to provide open pavement for right-turning traffic with large turning paths. A right-turn slip lane can accommodate vehicles with large turning paths but should discourage high-speed vehicle turns and improve the right-turning motorist's view of other users.

TIME FRAME ●○○

Many treatments addressing pedestrian and bicyclist improvements can be implemented in relatively short time frames.

COSTS ●○○○

Costs will vary depending on the treatment implemented. Many are low cost in nature. Others, such as overpasses and lane widening, will cost significantly more.

EFFECTIVENESS

TRIED/PROVEN: The presence of sidewalks on both sides of the street has proven to significantly reduce the "walking along roadway" pedestrian crash risk compared to locations where no sidewalks/walkways exist. Reductions of 50 to 90% of these types of pedestrian crashes have occurred. The Federal Highway Administration found that a raised median (or raised crossing island) was associated with a significantly lower pedestrian crash rate at multilane crossing locations, with both marked (46% reduction) and unmarked (39% reduction) crosswalks. In contrast, painted (not raised) medians and center two-way left-turn lanes did not offer significant safety benefits to pedestrians on multilane roads, compared to no median at all. A Danish study concluded that providing bicycle lanes can reduce bicycle crashes by 36%.

COMPATIBILITY

These strategies are generally compatible with other signalized intersection safety strategies.

SUPPLEMENTAL INFORMATION

Improvements to pedestrian facilities are discussed in detail in *NCHRP Report 500: Volume 10*. More details on design of sidewalks and walkways, including curb ramps, may be found in the FHWA report *Designing Sidewalks and Trails for Access, parts 1 and 2*. (safety.fhwa.dot.gov)

For more details on this and other countermeasures: http://safety.transportation.org

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Revise Geometry of Complex Intersections

WHERE TO USE

Signalized intersections with high levels of crashes on a leg where other low-cost strategies have not been successful or are not considered appropriate.

Photo by: Texas Transportation Institute

In this photo, the photographer's vehicle is in the through lane. Note that it is aligned with the opposing left turn lane requiring a shift to the right when traveling through the intersection.

DETAILS

Some geometric problems with signalized intersections will not be remedied using signing, channelization, or signal phasing. Physical modifications to all or part of an intersection may be needed to reduce severe crash rates. There may be multiple problems associated with one or more movements at the intersection that can be best addressed with significant improvements to intersection design. Because of the extensive reconstruction required to implement these strategies, they will not be appropriate for agency programs designed for quick, low-cost action.

For some signalized four-leg intersections with very low through volumes on the cross street, the best method of improving safety may be to convert the intersection to two T intersections. The intersections should be separated enough to ensure the provision of adequate turn-lane channelization on the major road. If through volumes are high, the intersection may be safer if left as a conventional four-leg intersection. Converting it to two T intersections would only create excessive turning movements at each of the T intersections.

For some signalized offset T intersections with very high through volumes on the cross street, the best method for improving safety may be to convert the intersection to a single four-leg intersection.

Roads that intersect with each other at angles less than 90 degrees can present sight distance and operational problems for drivers. A high incidence of right-angle crashes, particularly involving vehicles approaching from the acute angle, may be the result of a problem associated with skew. Vehicles have a longer distance to travel through the intersection, and drivers may find it difficult to turn their heads and necks to view an approach on an acute angle.

Skewed intersections (with the angle of intersection less than 75 degrees) pose particular problems for older drivers. A restricted range of motion reduces the older drivers' ability to effectively scan to the rear and sides of their vehicles to observe blind spots. They may also have trouble identifying gaps in traffic when making a left turn or safely merging with traffic when making a right turn.

Other techniques to consider are: removing deflection in the through-vehicle travel path, redesigning the intersection approach, and closing the intersection leg.

KEY TO SUCCESS

The key to success for a project of this type is conducting an adequate system traffic study to ensure that the safety and other operational problems are not merely transferred from the intersection being treated to other locations.

ISSUES

Diverted traffic may contribute to safety or operational problems at adjacent intersections or on alternative routes, resulting in no net benefit. Owners of properties where access would be reduced, especially owners of commercial operations, may oppose this strategy.

Care should be taken during the transition period, both before and after the intersection leg is closed, to alert drivers to the changes as they approach the section involved.

Design solutions—including mountable curbs and vegetation or other barriers that can be driven through or over in an emergency—may need to be considered.

TIME FRAME ●●●

This strategy will likely require an implementation time of at least one year to provide time to work out the details of street closure and to communicate the plan to affected business owners and residents.

COSTS ●●●●

Costs to implement this strategy are highly variable. Where mere closure of an intersection leg is all that is needed, costs are low, especially if the closure will be implemented with barricades or other low-cost devices. In other cases, modifications to the intersection may require substantially higher expenditures.

EFFECTIVENESS

TRIED/PROVEN: Determination of the effectiveness is site specific, due to the varying conditions at intersections where these strategies may be employed. One study in 1976 indicated offset intersections had crash rates approximately 43% of the crash rates at comparable four-leg intersections.

COMPATIBILITY

These strategies are generally compatible with other signalized intersection safety strategies, and are primarily appropriate for urban and suburban intersections where reasonable alternative access or routes are readily available.

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Construct Special Solutions

WHERE TO USE

Signalized intersections with high frequencies of crashes that are not reduced through other lower-cost solutions.

Photo by: FHWA

DETAILS

Signalized intersections may have such a significant crash problem that the only alternative is to change the nature of the intersection itself. Thus, low-cost, short-term solutions will often not be available. Implementing these strategies will necessitate significant public involvement and stakeholder activity.

Safety problems associated with left turns at signalized intersections are magnified at intersections with high volumes of left turns. Indirect left-turn treatments, such as jughandles before the crossroad, directional median crossovers, and loop roadways beyond the crossroad, can address both safety and operational problems related to left turns. These treatments remove the left-turning vehicles from the traffic stream without causing slow down or stoppage in a through-traffic lane. Right-angle crashes are also likely to decrease after implementation. Alternative left-turn designs are discussed in various publications and included in the Federal Highway Administration (FHWA) *Signalized Intersection Guide*.

A roundabout can have a better crash experience than a conventional signalized intersection (for low– to medium–volume roads). Consult the FHWA's *Roundabouts: An Informational Guide* for the current state of the practice on the design, operation, and safety of roundabouts. Refer to Unsignalized Strategy F3 for more detailed information.

When two-way streets are converted to one-way streets (typically in a central business district environment), it is generally to increase capacity, but removing opposing traffic flows can improve safety as well. Removing one direction of traffic from a two-way street allows better signal

synchronization and progression of platoons. Smooth progression and reduced congestion can reduce rear-end crashes. Removing one direction of traffic can improve safety by

- reducing the number of vehicle-vehicle conflict points at intersections,
- allowing for unopposed turn maneuvers,
- simplifying operations and signal phasing at multileg intersections,
- allowing pedestrians to have to deal with traffic from only one direction, and
- providing more gaps for vehicles and pedestrians at unsignalized crossings.

Safety-related drawbacks to conversion to one-way streets may include the following:

- pedestrians may not look in the correct direction for oncoming vehicles.
- minor sideswipe crashes related to weaving maneuvers may occur.
- supplemental and redundant signing is recommended.
- transit operations may be adversely affected.
- increase in vehicle speed may occur.

Consider providing a grade separation or interchange for signalized intersection locations with extremely high volumes, extremely poor crash histories, or other mitigating factor(s). Other solutions may include quadrant design, superstreet, and diverging diamond designs.

KEY TO SUCCESS

Major construction projects have a greater chance of success when all key stakeholders—including owners of nearby businesses, transit agencies, neighborhood/resident groups, and other primary users of the intersection—get involved.

TIME FRAME ●●●

In general, the time frame for most projects of this magnitude is lengthy.

COSTS ●●●●

Costs will generally be high when constructing special solutions.

EFFECTIVENESS

TRIED: It is expected that these strategies will reduce both rear-end collisions resulting from the conflict between vehicles waiting to turn left and following vehicles and right-angle collisions resulting from the conflict between vehicles turning left and oncoming through vehicles.

COMPATIBILITY

With major changes to an intersection, other solutions are not likely to be appropriate and not necessarily compatible.

SUPPLEMENTAL INFORMATION

Refer to the *FHWA Signalized Intersections: Informational Guide* for more information on this strategy.

For more details on this and other countermeasures: http://safety.transportation.org

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Clear Sight Triangles

WHERE TO USE

Signalized intersections where there is a high frequency of crashes between vehicles turning right on red from one street and through vehicles on the other street or crashes involving left turning traffic where landscaped medians are present.

Photo by: Texas Transportation Institute

DETAILS

Sight distance improvements can often be achieved at relatively low cost by clearing sight triangles to restore sight distance obstructed by vegetation, roadside appurtenances, buildings, bus stations, or other natural or man-made objects.

Since sight distance is a greater issue at intersections with stop control than at signalized intersections, more research has been performed on the effectiveness of sight distance improvements at stop-controlled intersections. There are several movements at signalized intersections that operate similarly to stop-controlled intersections (such as right turn on red and permitted left turns) for which expected effectiveness of sight distance improvements at signalized intersections may be inferred from similar studies at stop-controlled intersections. Such estimates should be performed with caution, taking into consideration the other characteristics of signalized intersection operation that would alter the effectiveness estimates. Sight distance obstructions can also affect visibility of pedestrians by vehicles turning right on green.

Refer to Unsignalized Strategies C1 and C2 for more information.

KEY TO SUCCESS

A key to success for this strategy is effective diagnosis of whether a specific crash pattern observed at an intersection is, in fact, related to restricted sight distance. Currently this is a judgment made by an experienced safety analyst.

ISSUES

The most difficult aspect of this strategy is the removal of sight restrictions located on private property. The legal authority of highway agencies to deal with such sight obstructions varies widely, and the time (and possibly the cost) to implement sight distance improvements by clearing obstructions may be longer if those obstructions are located on private property. If the object is a mature tree or planting, then local concerns over adverse environmental consequences may arise. For a more detailed discussion of trees, see *NCHRP Report 500: Volume 3*.

TIME FRAME ●○○

Projects involving clearing sight obstructions on the highway right-of-way can typically be accomplished in three months or less, assuming the objects are readily moveable. Clearing sight obstructions on private property requires more time for discussions with the property owner.

COSTS ●○○○

Costs will generally be low, assuming that in most cases the objects to be removed are within the right-of-way.

EFFECTIVENESS

TRIED: Research has established a relationship between intersection safety and sight distance at unsignalized intersections (5% reduction in crashes per quadrant). No such research quantifies the effectiveness of improving sight distance at signalized intersections. One may expect that crashes related to inadequate sight distance (specifically, angle and turning related) would be reduced if the sight distance problems were improved. However, because the signal assigns right-of-way for most vehicles crossing paths at right angles and because traffic volumes affected by the other situations cited above are low, the overall impact on crashes could be relatively small.

For jurisdictions that operate signals on late-night flash, these intersections effectively operate as two-way stop control. Therefore, clearing sight triangles would have an impact on safety.

COMPATIBILITY

This strategy can be used in conjunction with most other strategies for improving safety at signalized intersections.

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Redesign Intersection Approaches

WHERE TO USE

Signalized intersections with safety problems related to sight distance that cannot be addressed with less expensive methods.

Photo by: FHWA

DETAILS

If other less expensive methods cannot be used or are ineffective, horizontal or vertical (or both) realignment of approaches may be a solution. Realigning both of the minor road approaches so that they intersect the major road at a different location, or a different angle, can help address horizontal sight distance issues.

This is a high-cost, longer-term treatment for the intersection, but if completed according to applicable design policy, it should help alleviate crashes related to sight distance. The AASHTO *Policy on Geometric Design of Highways and Streets* contains sight distance guidelines, and these guidelines should be considered when revising intersection approach geometry.

An intersection leg can be closed or can be made one-way away from the intersection in order to address sight distance issues related to that particular leg. Intersection relocation and closure, elimination of intersection skew, and offsetting of left-turn lanes are all strategies that involve improvements to approach alignment to improve sight distance.

KEY TO SUCCESS

There are significant right-of-way and property access issues involved in this strategy, and public information campaigns are vital to the success of the intersection improvements.

ISSUES

Owners of properties where access would be reduced, especially owners of commercial operations, may oppose this strategy. Thus, careful evaluation of the potential impacts of proposed improvements is needed to avoid or minimize such problems.

TIME FRAME ●●●

This strategy requires a long implementation time. At least one year is necessary to work out the details of intersection approach realignment and to communicate the plan to affected businesses owners and residents. Where relocation requires right-of-way acquisition and/or demolition of existing structures, an extensive project development process of up to four years may be required.

COSTS ●●●●

The costs to change the horizontal or vertical alignment of an intersection approach are usually high. Furthermore, additional right-of-way will generally need to be acquired.

EFFECTIVENESS

TRIED: Implementing any of these strategies should improve safety at signalized intersections. More research is needed to better quantify estimates of crash reduction for these countermeasures.

COMPATIBILITY

This strategy can be used in conjunction with other strategies for improving safety at signalized intersections.

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Improve Visibility of Intersections on Approach(es)

WHERE TO USE

Signalized intersections with a high frequency of crashes attributed to drivers being unaware of the presence of the intersection.

Photo by: FHWA, Texas Transportation Institute

DETAILS

Some crashes at signalized intersections may occur because drivers are unaware of the presence of an intersection or are unable to see the traffic control device in time to comply. The ability of approaching drivers to perceive signalized intersections immediately downstream can be enhanced by signing, delineation, lighting, and warning devices.

Improve Signing and Delineation. Installing or upgrading signs and pavement markings on intersection approaches can help better prepare drivers for the intersection ahead. This may include advance guide signs, advance street name signs, warning signs, pavement markings, overhead street signing, and post-mounted delineators. Advance warning signs, with or without flashers, can also alert drivers to an intersection. Installing advance warning signs on both sides of the roadway (signing redundancy) may be appropriate in some situations. Street name and lane assignment signs in advance of the intersection prepare drivers for choosing and moving into the lane they need. Signs and flashers warning drivers of a red signal might improve awareness of the intersection and the red signal. Providing a break in pavement markings at intersections also helps to alert drivers.

Install Larger Signs. Installing signs with larger letters can enhance the visibility of intersections with existing regulatory and warning signs and the ability of drivers to perceive signs. The Federal Highway Administration (FHWA) *Older Driver Highway Design Handbook* encourages installation of larger signs to benefit older drivers.

Provide Intersection Lighting. Providing lighting at the intersection or at both the intersection and on its approaches can enhance driver awareness of the intersection and reduce nighttime crashes.

Install Rumble Strips on Approaches. Rumble strips can be installed on intersection approaches transverse to the travel direction to alert drivers to the intersection and the traffic control used. Rumble strips are particularly appropriate on intersections where a pattern of crashes related to lack of driver recognition of the signal's presence is evident, often on high-speed approaches. This

strategy should be used sparingly. Rumble strips are normally applied when less intrusive measures have been tried but failed to correct the crash pattern.

Install Advance Detection Systems. Two techniques that have been tried on rural high-speed approaches are "queue detection" and "dilemma zone protection". The former can be used where the ends of potentially long queues may not be visible to approaching drivers due to sight distance problems. The latter can assist drivers (esp. heavy vehicle operators) caught in the dilemma zone by extending green times.

KEY TO SUCCESS

A key to success with this strategy is to select a combination of signing and delineation techniques appropriate to specific conditions. This engineering assessment should, where possible, be accompanied by a human-factors assessment of signing and delineation needs.

ISSUES

Care should be taken not to overuse traffic signing, which would cause drivers not to recognize intersections. Maintenance of signs and pavement markings is also important to the strategy's success. Retroreflectivity of older pavement markings and signs should be checked periodically.

TIME FRAME ●○○

This strategy does not require a long development process. Signing and delineation improvements can typically be implemented in three months or less.

COSTS ●○○○

Costs to implement signing and delineation are relatively low. An agency's maintenance costs may increase. Crash data should be studied to ensure that safety at the intersection could be improved by providing lighting. The costs involved with intersection lighting may be moderately expensive.

EFFECTIVENESS

TRIED: Making drivers aware of approaching an intersection through the use of enhanced signing and delineation should improve safety by alerting drivers to potential vehicles on the cross streets. This heightened awareness will quicken drivers' reaction times when conflicts occur. The Institute of Transportation Engineers has reported that installing advance warning signs for signalized intersections can reduce all crashes by up to 22% and right angle crashes by 35%. One study concluded that providing advanced dilemma zone protection on rural high-speed approaches may reduce crashes by up to 39%.

COMPATIBILITY

This strategy can be used in conjunction with most other strategies for improving safety at signalized intersections.

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Improve Visibility of Signals and Signs at Intersections

WHERE TO USE

Signalized intersections with a high frequency of right-angle and rear-end crashes occurring because drivers are unable to see traffic signals and signs sufficiently in advance to safely negotiate the intersection being approached.

Photo by: FHWA

DETAILS

Lack of visibility of traffic control devices may contribute to crash experience at signalized intersections. Visibility of traffic signals and signs at intersections may be obstructed by physical objects or may be obscured by weather conditions. Also, a driver's attention may be focused on other objects at the intersection, such as extraneous signs. Poor visibility of signs and signals may result in vehicles not being able to stop in time for a signal change or otherwise violating the intended message of a regulatory or directional sign. Providing adequate visibility of signs and signals also aids in drivers' advance perception of the upcoming intersection. The Federal Highway Administration (FHWA) *Older Driver Highway Design Handbook* should be consulted to ensure that improvements to visibility of traffic control devices will be adequate for older drivers (www.tfhrc.gov).

In addition to potentially restricting driver sight lines, large numbers of appurtenances and signage not associated with the driving task in the vicinity of an intersection can impose a high workload. This visual clutter can make it difficult for the driver to extract the information from the signs required to execute the driving task.

Maintenance of signals and signs is important to the visibility of the devices. If visibility of traffic control devices is considered to be a potential factor in crashes, a field review should be performed to determine if part of a sign's message is covered, obliterated, or blocked, as well as to check the reflectivity of the sign.

Methods for improving visibility of traffic signals and signs include the following:

- installing an additional signal head;
- providing visors to shade signal lenses from sunlight;
- providing louvers, visors, or special lenses so drivers are able to view signals only for their approach;

- installing backplates;
- installing larger (12-inch) signal lenses;
- removing or relocating unnecessary signs; and
- providing supplemental near-side and/or far-side signal faces.

Additional information on improving signal visibility to reduce red-light running can be found in *Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running* (available from ntl.bts.gov).

KEY TO SUCCESS

Visibility and clarity of the signal should be improved without creating additional confusion for drivers. Additional signing to warn drivers should not clutter the intersection and should not present confusing or conflicting messages to drivers.

ISSUES

Care should be taken to ensure that new or relocated signs do not present additional sight distance, roadside, or driver' distraction hazards. If some of the devices recommended are not maintained properly, the expected benefits may be lost.

TIME FRAME ●○○

Implementation time will be relatively short for procedures to install new signs, improve signals, and remove or relocate signs.

COSTS ●○○○

Costs will be low for most procedures to install or upgrade signs and signals to improve visibility and awareness of the traffic control devices. Ongoing maintenance costs should be included when considering use of these devices.

EFFECTIVENESS

TRIED/PROVEN: Improved visibility and awareness of traffic control information are expected to reduce conflicts related to drivers not being able to see the device well or in enough time to comply with the signal indication or sign message (such as those resulting in rear-end and right-angle crashes). Various studies have indicated that installing larger (12-inch) signal lenses may result in an 11% decrease in crashes, installing backplates may result in a 13% decrease in crashes, converting from pedestal-mounted to mast arm–mounted signals may reduce crashes by up to 49%, and installing additional heads may reduce crashes by up to 28%.

COMPATIBILITY

Actions taken to improve visibility of signals are compatible with most other strategies to improve signalized intersection safety.

For more details on this and other countermeasures: http://safety.transportation.org

For more information contact:

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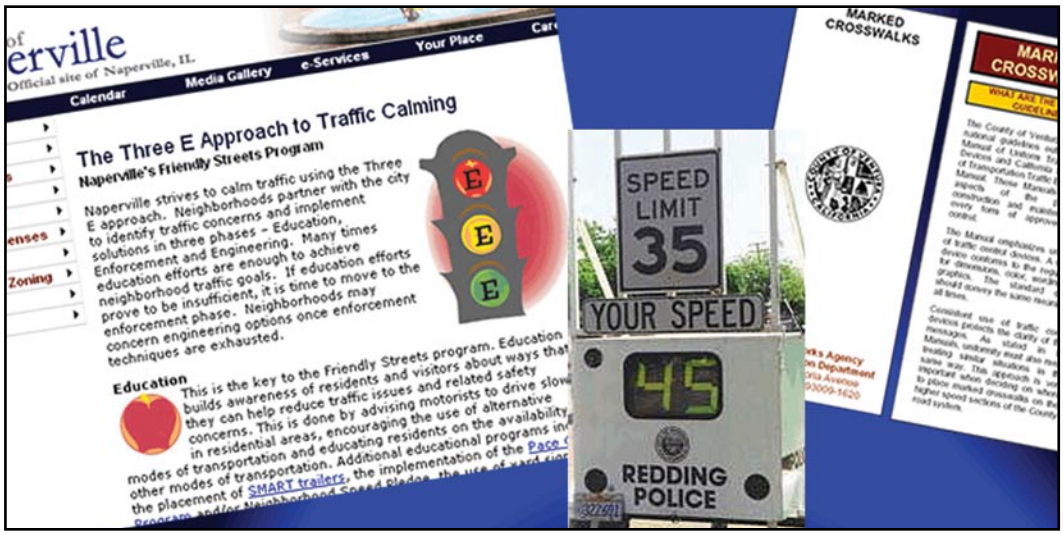
Provide Public Information and Education

WHERE TO USE

Signalized intersections with a high frequency of crashes related to drivers either being unaware of (or refusing to obey) traffic laws and regulations that impact traffic safety (especially red-light running, speeding, and not yielding to pedestrians).



DETAILS

Providing targeted public information and education (PI&E) on safety problems at intersections is a preventive measure that can help improve driver compliance with traffic control devices and traffic laws. PI&E programs generally add effectiveness to targeted enforcement programs as well.

Another option is to develop public information campaigns aimed at specific drivers who violate regulations at intersections, even though it is often difficult to identify and focus upon a subset of the driving population using a specific intersection. Therefore, an area-wide program is often the preferred approach. Targeted drivers need to be defined both in terms of the location of the hazardous intersection(s) and the attributes of the drivers who may have been identified as overrepresented in the population involved in crashes. More information on public information that is targeted at specific drivers is provided in *NCHRP Report 500: Volume 5*.

KEY TO SUCCESS

Keys to success include identifying and reaching as much of the intended audience as possible, providing information in non-technical terms, and providing agency personnel to answer questions and calls from the public. This can be done through television, Internet, radio, distribution of flyers, driver education classes, or other methods.

It is important to motivate people to drive, bike, or walk safely. Since unsafe actions do not always result in crashes, road users may have a false sense of security and may not see the need to drive more safely or follow traffic regulations in all circumstances.

Use of trained public information specialists is important for program success. Establishing good relationships with media representatives will be extremely helpful for maximizing coverage and impact.

ISSUES

The primary potential difficulty associated with this strategy is relating the importance of informational/educational programs to the public. Websites, brochures, posters, and advertisements can be effective if they are conspicuous and readily available. Use of electronic media is expensive, unless strategies are employed for receiving donated time. Consideration should be given to people who may need materials in languages other than English or in alternative formats to accommodate disabilities. Another difficulty is maximizing the reach of a public involvement program.

TIME FRAME ●○○

Implementation time for this strategy should be short to moderate. Extensive planning of the program and design of the educational materials can lengthen the implementation time.

COSTS ●○○○

Costs will generally be low to moderate and depend upon the kinds of materials developed (Internet, brochures, posters, radio, or television advertisements), the extent of effort spent on designing the materials, and the amount of free media coverage that can be achieved.

EFFECTIVENESS

TRIED: Data on the effectiveness of this strategy for this specific application are not known, but it is expected that providing information to drivers will help improve safety at intersections. It may not be possible to identify or reach the entire audience that would benefit from a PI&E campaign.

COMPATIBILITY

This strategy can be used in conjunction with the other strategies for improving safety at signalized intersections. It may be used in conjunction with overall traffic safety public service campaigns.

SUPPLEMENTAL INFORMATION

There is a potential need for cooperation among various media agencies to effectively implement the selected strategy. A media specialist should be involved from the initial stage of project planning. Also refer to *Countermeasures That Work* from the National Highway Traffic Safety Administration.

For more details on this and other countermeasures: http://safety.transportation.org

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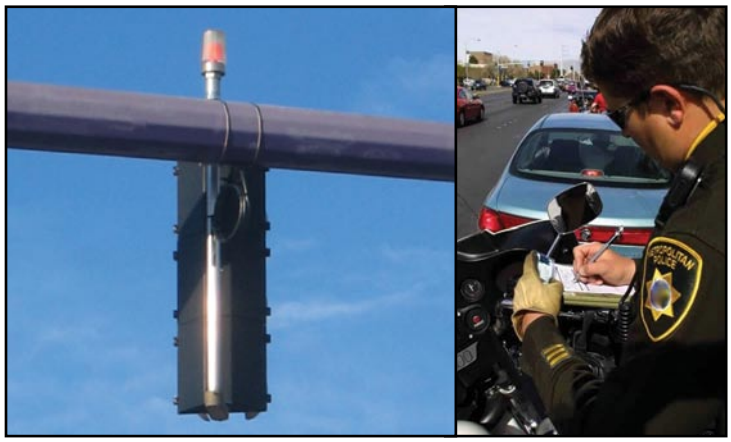
Provide Targeted Conventional Enforcement of Traffic Laws

WHERE TO USE

Signalized intersections with a high frequency of crashes related to drivers either being unaware of (or refusing to obey) traffic laws and regulations that impact traffic safety.



Photos by: FHWA

Tell tale lights assist police officers by allowing them to sit downstream of the traffic signal and know when the red indication is displayed.

DETAILS

Enforcement is a potential countermeasure to unsafe and illegal motorist behavior at intersections. Studies report the reduction of traffic law violations when enforcement is used. Traffic law enforcement agencies will often select locations for targeted enforcement when crash, citation, or other sources of information suggest that the site is unusually hazardous due to illegal driving practices, such as speeding or red-light running. These actions can lead to rear-end, head-on, sideswipe, angle, and pedestrian- or bicycle-related crashes.

Traffic law enforcement methods vary depending upon the type of program being implemented. For background on methods and approaches, refer to the publications available on the National Highway Traffic Safety Administration website (http://www.nhtsa.dot.gov/people/injury/enforce/).

KEY TO SUCCESS

It is important to correctly identify intersections that would benefit from enforcement. Care should be taken to first ensure that the existing signals are operating properly, are visible, and meet *Manual on Uniform Traffic Control Devices* requirements, as well as that timing plans—including clearance intervals—are appropriate. Analysis of crash statistics can help with this process, as can spot speed or conflict studies. In some cases, public input or observations by law enforcement personnel may suggest that a location should be targeted for enforcement.

ISSUES

Police officers providing targeted enforcement of red-light running can be aided by "telltale" or "tattle-tale" lights. These lights are placed at traffic signals but face away from oncoming traffic. Police officers are able to wait in their vehicles on the downstream side of the traffic signal and view the tattle-tale light. This way, they are able to pursue red-light runners without also running through the red light themselves (and possibly into vehicles entering the intersection from the cross street).

TIME FRAME ●○○

Targeted enforcement can be implemented in a very short time.

COSTS ●●○○

Costs are low to moderate, depending upon the availability of law enforcement personnel.

EFFECTIVENESS

TRIED: Targeted enforcement of traffic laws is a short-term, moderate-cost measure to address site-specific signalized intersection safety. Though this is an effective strategy, the effectiveness has often been found to be short lived. It is difficult—if not impossible—to provide constant enforcement of traffic regulations due to funding and staffing reasons, so periodic enforcement may be necessary to sustain the effectiveness of this strategy.

COMPATIBILITY

This strategy can be used in conjunction with the other strategies for improving safety at signalized intersections. It may be used in conjunction with overall traffic safety public service campaigns.

SUPPLEMENTAL INFORMATION

Targeted enforcement at intersections is also discussed in the Unsignalized Intersection Fact Sheet G1 and H1. A media specialist should be involved from the initial stage of project planning. Also refer to *Countermeasures That Work* from the National Highway Traffic Safety Administration.

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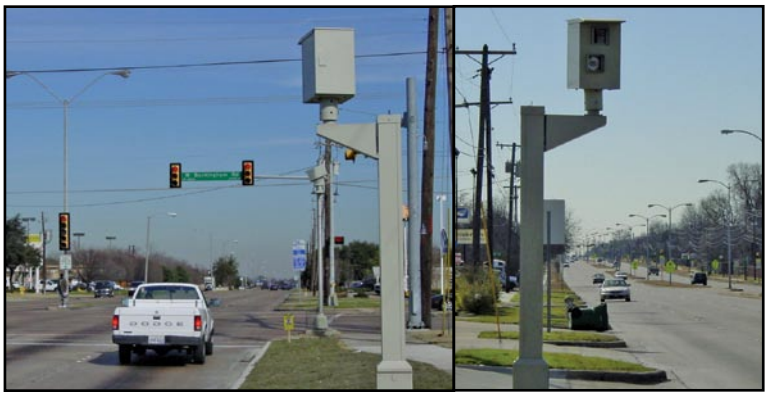
Implement Automated Enforcement of Red-Light Running (Cameras)

WHERE TO USE

Signalized intersections with a high frequency of right-angle and rear-end crashes attributed to drivers who intentionally disobey red signal indications.



Photos by: Texas Transportation Institute

These photos show the front and rear of a typical red light camera installation.

DETAILS

Red-light running is a well-documented traffic safety problem. Various engineering countermeasures can address some occurences of red-light running. Such countermeasures are discussed in *Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running* (available from ntl.dot.gov). In some instances, inappropriate driver behavior is the primary problem. Because police officers cannot enforce traffic signals as often or as widely as an agency might need, automated enforcement is an attractive alternative.

Automated enforcement refers to the use of photo and video camera systems connected to the signal control. Such systems record vehicles proceeding through the intersection after the signal displays red. Red-light running cameras turn on after the signal turns red. A detector senses approaching vehicles and sends a signal to the camera, which photographs vehicles as they enter the intersection. Data on the violation are printed on the photograph. Police officers review the photos to verify a violation occurred prior to mailing the citation. More information in the operational aspects of such systems can be found in *Red-Light Camera Systems Operational Guidelines* (available from safety.fhwa.dot.gov).

KEY TO SUCCESS

Acceptance by local stakeholders—including officials, the public, and local law enforcement — is key to successful red-light running programs. A public information campaign explaining the program, the need for it, how the cameras work, and the potential benefits are key to successful implementation. Signs informing the public that automated enforcement is being used are frequently used.

Successful red-light camera programs have generally begun as safety improvement programs. Programs that are perceived as revenue generators are generally not well accepted.

Both the highway and law enforcement agencies in the jurisdiction should jointly plan and operate the program. Moreover, where private contractors are used to implement parts of the program, their contract and compensation should not be directly linked to revenue or tickets issued. Some programs have lost public support because it was perceived that a private company was profiting from traffic ticket revenue.

ISSUES

Arguments against this strategy include violation of personal privacy or constitutional rights, lower effectiveness than other types of enforcement, cost outweighing the benefits, and implementation solely to generate revenue. Recent challenges also include questioning the precision and proper setting of the cameras. The Institute of Transportation Engineer's *Automated Enforcement in Transportation* addresses these arguments. Timeliness of the citation is important. Minimize the time between the violation and the mailing of the citation. The issue of tollerance (as it relates to time into the red interval that the voilation occured) must also be addressed.

TIME FRAME ●●○

The need for new legislation and the extent of public involvement can affect implementation time.

COSTS ●●○○

Costs may vary, depending upon the public information effort and the need for additional legislation. Equipment costs can vary due to the type of camera used. Costs also include monitoring the videotapes, issuing citations, maintaining collections and records, maintaining equipment, maintaining quality control, and rotating or moving the equipment from location to location.

EFFECTIVENESS

PROVEN: Several studies have shown the effectiveness of automated red-light enforcement in reducing red-light violations and crashes related to those violations. Fairfax, Virginia, experienced a 44% reduction in violations during the first year of operation. Two other sites in the city that did not have cameras experienced decreases in violations of 34%. Control sites in nearby counties experienced little change. Oxnard, California, experienced approximately 41% fewer red-light violations within a few months of installation. FHWA has made a general estimate of a 15% reduction in red-light running incidents resulting from these programs.

The ITE report *Automated Enforcement in Transportation* (available from www.ite.org) contains information on experiences with red-light running cameras in other jurisdictions. The programs experienced a range of reduction in violations of 23 to 83%. Another study concluded that red-light camera enforcement can reduce crashes at urban signalized intersections up to 11% and left-turn crashes by up to 45%.

COMPATIBILITY

This strategy can be used in conjunction with the other strategies for improving safety at intersections and should be accompanied by a public information or outreach campaign to explain the program.

For more details on this and other countermeasures: http://safety.transportation.org

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Implement Automated Enforcement of Approach Speeds (Cameras)

WHERE TO USE

Signalized intersections with a high frequency of crashes attributed to drivers who intentionally disobey posted approach speed limits.

Photo by: FHWA

DETAILS

Enforcement of traffic regulations is an important part of an overall intersection safety improvement strategy, but limited resources constrain the efforts police can devote to providing speed enforcement. Traffic law enforcement agencies will often select locations for targeted enforcement when crash, situation, or other sources of information suggest that the site is unusually hazardous due to illegal driving practices. Crash types that might indicate speeding as a concern include right-angle and rear-end collisions. Speed enforcement cameras (also known as photo radar) are a potential method to use in these locations.

KEY TO SUCCESS

A key to the success of this strategy is planning the enforcement and prioritizing the intersections that need it. Such intersections should have a combination of high-speed violation rates and related crash patterns. In some cases, public input or observations by law enforcement personnel may suggest that a location should be targeted with enforcement.

It is important that both the highway agency and the local law enforcement agencies be involved jointly in planning and operating the program. Another critical key to the success of an automated enforcement program is public awareness and acceptance.

ISSUES

There are many opponents to speed enforcement cameras. Arguments against this strategy include violation of personal privacy, violation of constitutional rights, lower effectiveness than other types of enforcement, high cost outweighing the benefits, accuracy of the devices and the settings,

and perceived implementation solely to generate revenue. Legislation may be necessary before implementing an automated enforcement program. Most enforcement agencies will allow for some tolerance before a citation is issued.

TIME FRAME ●●○

The time to implement speed enforcement cameras can vary somewhat, depending upon the extent of public involvement, the need to purchase new equipment, and the need for new legislation.

COSTS ●●○○

Costs may vary depending upon the effort put into public information and the need for additional legislation. Equipment costs can vary somewhat due to the type of camera selected (i.e., 35 mm, video, or digital), collections and records maintenance, and equipment maintenance.

EFFECTIVENESS

TRIED: Automated enforcement of speeds may provide a longer-term effect than on-site enforcement by police officers. It is not feasible to provide officers to constantly enforce speed limits, but a camera is more flexible regarding the duration it can operate.

Several agencies have shown reductions in crashes after speed enforcement cameras were installed. Paradise Valley, Arizona, experienced a 40% decrease in crashes after it began using a camera mounted in a mobile vehicle. In National City, California, a 51% decrease in crashes was experienced in the six-year period following installation of a camera unit in a mobile vehicle in 1991.

However, another study claims that more than half of the 18 studies evaluating automated enforcement programs have serious methodological problems, thereby negating the validity of their positive results.

Yet another study showed that photo radar and speed display boards had about the same effectiveness, reducing mean speeds by 5.1 and 5.8 miles per hour (mph), respectively, where baseline speeds averaged 34 to 35 mph in 25-mph zones. All speed control devices produced more noteworthy results on speeds 10 mph or more over the 25-mph speed limit. At the experimental site, the photo radar reduced these excessive speeds by 30%; the speed display board reduced them by 35%, and the enforced display board by 32%. However, these significant speed reduction capabilities were not sustained after the devices were removed. Researchers noted one long-term, statistically significant effect with the unenforced display board: a 1.7-mph decrease in speed continued at the experimental site after the display board was gone.

COMPATIBILITY

This strategy can be used in conjunction with the other strategies for improving safety at intersections.

For more details on this and other countermeasures: http://safety.transportation.org

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Control Speed on Approaches

WHERE TO USE

Signalized intersections with a high frequency of crashes attributed to drivers who intentionally disobey posted approach speed limits.

Photos by: FHWA

DETAILS

Since speed contributes to crash severity, lowering speeds on approaches to intersections can help reduce the severity of crashes. Slowing vehicle speeds on intersection approaches can improve safety for motorists, pedestrians, and bicyclists. Various techniques for attempting to control speeds on approaches involve geometric design, signal control technology, and other traffic calming treatments.

While warning signs or reduction of speed limits on an intersection approach cannot be expected to be extremely effective in lowering speeds, redesign of the approach can be more effective. Construction of a horizontal curve with an appropriate design speed could accomplish speed reduction. However, the curve should be designed so as not to create problems related to violations of driver expectancy or limited sight distance to the intersection, signed and delineated.

Some jurisdictions are using signal control technology to change the signal indication to red when a vehicle is detected traveling at a speed significantly over the speed limit on the approach to the intersection. Speeding vehicle–activated traffic signals have been deployed in the northern Virginia suburbs of Washington, D.C. Additional information can be found on the USDOT's Intelligent Transportation System Joint Program Office (ITS JPO) website (http://www.its.dot.gov/).

A raised intersection is another example of a design that could be implemented to slow vehicles. Traffic calming is not intended to be used in place of a signal that meets warrants but can be used as a method of addressing crash severity if designed to slow vehicle speeds. Roadway treatments such as chicanes, speed tables, and reduced lane widths through widening sidewalks or landscaped areas can be used to slow speeds on roadway approaches to intersections.

Traffic calming strategies are typically intended to reduce vehicle speeds or traffic volumes on collector and local streets. A main benefit of traffic calming is the potential improvement in pedestrian safety. The history of traffic calming is one centered upon neighborhood traffic management rather than collector and arterial streets. Care must be taken not to extend these methods beyond their range of appropriate application.

KEY TO SUCCESS

A key to the success of this strategy is careful planning and determination of the type of traffic calming measure viable for the specific intersection approach. Such intersections should have a combination of high speed-violation rates and related crash patterns.

ISSUES

Traffic calming measures are often controversial, especially when used to divert traffic from one road or street to another.

TIME FRAME ●●○

The implementation time for traffic calming measures will depend upon the type of measure used. Some types of traffic calming improvements may take three months or less, while others, especially when geometric improvements are required, may take one year or more.

COSTS ●●○○

The capital costs and maintenance costs involved in traffic calming measures vary depending on the type of traffic calming measure used. Some may be low cost, while others that require geometric design improvements and/or acquisition of right-of-way may be moderate cost.

EFFECTIVENESS

EXPERIMENTAL: No conclusive studies have been performed to determine the effectiveness of these strategies.

COMPATIBILITY

This strategy can be used in conjunction with most other strategies for improving safety at intersections.

SUPPLEMENTAL INFORMATION

The Institute of Transportation Engineers (ITE) has assembled information on traffic calming on its website. (http://www.ite.org/traffic/). The ITE site includes links to websites for organizations that are implementing traffic calming strategies. Traffic calming is discussed in the guide for crashes at unsignalized intersections *(NCHRP Report 500: Volume 5)* and in even more detail in the guide for crashes involving pedestrians *(Volume 10)*.

For more details on this and other countermeasures: http://safety.transportation.org

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Restrict Access to Properties Using Driveway Closures or Turn Restrictions

WHERE TO USE

Signalized intersections with high crash frequencies related to driveways adjacent to the intersection. Generally, driveways within 250 feet of the intersection are the greatest concern.

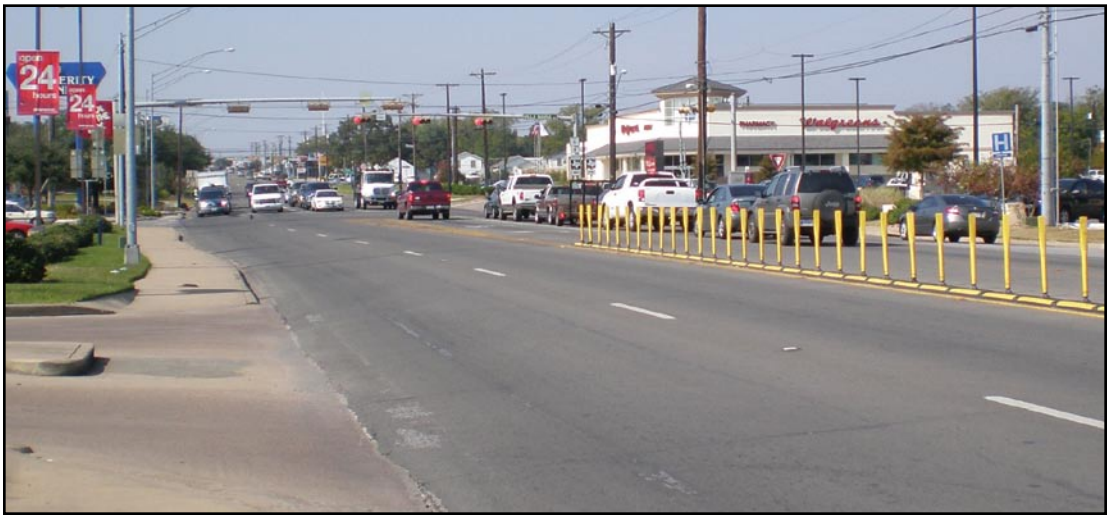

Photo by: Texas Transportation Institute

DETAILS

Restricting access to commercial properties near intersections by closing driveways on major streets, moving them to cross streets, or restricting turns into and out of driveways will help reduce conflicts between through and turning traffic. Such conflicts can lead to rear-end and angle crashes related to vehicles turning into and out of driveways and speed changes near the intersection and the driveway(s).

Locations of driveways on both the cross street and major street should be determined based on the probability that a queue at the signal will block the driveway. Directing vehicles to exits on signalized cross streets will help eliminate or restrict the access to the main roadway. Restricting turns to right-in and right-out only will address conflicts involving vehicles turning left from the road and left from the driveway.

Restricting access to properties is also discussed in greater detail in *NCHRP Report 500: Volume 5*.

KEY TO SUCCESS

Agencies should work with owners of adjacent properties to assure them that some restriction of access to their properties will improve safety and will not affect their ability (or, in the case of a retail business, their customers' ability) to reach their properties. Where practical, these strategies should be implemented as part of a comprehensive corridor access management plan.

ISSUES

Access restrictions could cause some owners of retail businesses to lose (or to think they will lose) customers. This is highly dependent on the type of business and the nature of the access restriction. Such impacts need to be carefully considered by highway agencies before implementing this strategy. It is advisable to involve stakeholders at the early stages of planning for these improvements.

TIME FRAME ●○○

Implementation of driveway closures and relocations can require three months to three years. While an extensive project development process usually is not required, discussions with affected property owners must be carried out to reach agreement on access provisions. Essential aspects of such an agreement may include driveway permits, easements, and driveway-sharing agreements. Where agreement cannot be reached, the highway agency may choose to initiate legal proceedings to modify access rights; such contested solutions are undesirable and require considerable time to resolve.

COSTS ●○○○

Costs are highly variable. These costs mostly involve acquiring access or constructing replacement access.

EFFECTIVENESS

TRIED: Further evaluations are needed to quantify the safety effectiveness of this strategy. Some of the states that have implemented access management policies include Iowa, Minnesota, and Florida.

COMPATIBILITY

This strategy can be used in conjunction with most other strategies for improving safety at signalized intersections and, in particular, those strategies discussed in the signalized fact sheet F2 (Restricting Cross Median Access).

SUPPLEMENTAL INFORMATION

Highway agencies should establish formal access management policies to guide the planning and permitting process and to provide a basis for remedial treatments at existing locations where driveway-related safety problems occur. For more information on access management, visit www.accessmanagement.gov.

For more details on this and other countermeasures: http://safety.transportation.org

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Restrict Cross-Median Access near Intersections

WHERE TO USE

Approaches to signalized intersections with a high frequency of crashes involving drivers making turns across medians.

Photo by: FHWA

DETAILS

When a median opening on a high-volume street is near a signalized intersection, it may be appropriate to restrict cross-median access for adjacent driveways. For example, left and U-turns can be prohibited from the through traffic stream, and left turns from adjacent driveways can be eliminated. Restrictions can be implemented by signing, by redesign of driveway channelization, or by closing the median access point via raised channelization. When access patterns are changed or restricted, the movements restricted in that location should be accommodated at a safe location nearby.

The optimal situation is to avoid driveway conflicts before they develop. This requires coordination with local land use planners and zoning boards in establishing safe development policies and procedures. Avoidance of high-volume driveways near congested, or otherwise critical, intersections is desirable. Driveway permit staff within agencies need to have an understanding of the safety issues related to driveways.

KEY TO SUCCESS

Provision of alternative locations for turning maneuvers is a key to the successful restriction of access at a median opening. Care should be taken to prevent the safety problems related to the median opening from being transferred to another location.

It is also important for land owners and affected persons to be involved early in the planning process. The quadrants of many signalized intersections are developed with commercial land uses that rely

on pass-by traffic. Demonstrating a linkage to the safety of their customers as well as the operational efficiency of the street serving their business can be a key to overcoming resistance to this strategy.

The most successful access management techniques rely on physical barriers to restrict movements. Reliance on signing and pavement markings only requires strong enforcement to be effective, which in many cases will not be feasible.

ISSUES

Restricting access at one location will cause turning movements to shift to another location. Care should be taken to ensure adequate capacity and access are provided to accommodate this and that the diversion to alternative access points will not create a safety problem.

Adjacent land owners, particularly commercial businesses, are generally opposed to closing and restricting access, which they believe will adversely affect their businesses.

TIME FRAME ●○○

Implementation of driveway closures and relocations can require three months to three years. While an extensive project development process usually is not required, discussions with affected property owners must be carried out to reach agreement on access provisions. Essential aspects of such an agreement may include driveway permits, easements, and driveway-sharing agreements. Where agreement cannot be reached, the highway agency may choose to initiate legal proceedings to modify access rights. Contested solutions are undesirable and require considerable time to resolve.

COSTS ●○○○

Costs of closing median access points are low, but the cost of providing access in other locations can vary. The materials and labor needed to install signing or additional median curbs or barriers may be low, but relocation of driveways could increase costs.

EFFECTIVENESS

TRIED: Restricting cross-median access is expected to eliminate conflicts related to vehicles using the median opening, as well as related rear-end and angle crashes.

COMPATIBILITY

This strategy can be used in conjunction with the other strategies for improving safety at signalized intersections.

SUPPLEMENTAL INFORMATION

Highway agencies should establish formal access management policies to guide the planning and permitting process and to provide a basis for remedial treatments at existing locations where driveway-related safety problems occur. For more information on access management, visit www.accessmanagement.gov.

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Improve Drainage in Intersection and on Approaches

WHERE TO USE

Signalized intersections with a high frequency of crashes that are related to poor drainage. Such crashes involve vehicles that hydroplane and, hence, are not able to stop when required.

Photos by: unknown (l), Dan Burden (r)

DETAILS

One of the most important principles of good highway design is drainage. Drainage problems on approaches to, within, and between intersections can contribute to crashes. However, within an intersection, the potential for vehicles on cross streets to crash contributes to the likelihood for severe crashes, specifically angle crashes. Concentrated storm water must be intercepted at all intersection locations before it reaches the highway. Over-the-curb flow and surface water must be removed without interrupting traffic flow or causing a problem for vehicle occupants, pedestrians, or bicyclists.

Where greater volumes of truck traffic cause rutting in asphalt pavement, especially in the summer when the pavement is hot, consideration should be given to replacing the asphalt with a concrete pavement. Though this is more expensive than a flexible pavement, less rutting will occur, and repair of pavement damage due to trucks will be needed less frequently.

KEY TO SUCCESS

A key to success for this strategy is involving hydrologic and hydraulic specialists during the initial phases to ensure that proper considerations are given to drainage aspects.

Notification of proposed projects should be communicated to other agencies and the public. Any permits and regulations needed by the project should be identified as soon as possible so there are no delays due to legal processes. The success of this strategy will be significantly aided when provision is made for regular condition surveys of existing structures and hydraulic performance to evaluate the functionality of the improvements.

ISSUES

Problems related to drainage design include: lateral encroachments on a channel; pavement cross slopes; disruption of water supplies, irrigation facilities, or storm drainage systems; encroachments into environmentally sensitive areas; and failure to plan for right-of-way.

Increased maintenance costs and responsibilities due to change in material costs or drainage systems, regardless of how minor, may present problems in implementing drainage improvements. The legal implications that may be overlooked or not investigated thoroughly pose a serious potential problem. Overlooking a needed permit or regulation can delay a project for months.

TIME FRAME ●●○

Many small projects that could include drainage improvements, such as spot safety improvements, single bridge replacements, and similar work, are often planned and constructed within several months. Longer-term improvements sometimes require as much time to complete as construction of an entirely new section of highway.

COSTS ●●○○

While minor drainage improvements can be low cost, the costs involved in designing and implementing a drainage system are not incidental or minor on most roads. Careful attention should be given to adequate drainage and protection of the highway from floods in all phases of location and design.

Drainage is usually more challenging and costly for urban projects than for rural projects due to more rapid runoff rates and larger volumes of runoff, increases in cost due to potential flood damage to adjacent property, greater restrictions because of urban developments, lack of natural areas of water bodies to receive flood water, and higher volumes of traffic or pedestrians.

EFFECTIVENESS

TRIED: Improved drainage can help improve safety, increase traffic capacity, and increase pavement load capacity. However, there exists no adequate documentation of the effect on crash experience. It can be expected that improved drainage would reduce crashes related to hydroplaning.

COMPATIBILITY

This strategy can be used in conjunction with the other strategies for improving safety at signalized intersections.

SUPPLEMENTAL INFORMATION

Policy guidance on drainage design/techniques is discussed in AASHTO's *A Policy on Geometric Design of Highways and Streets* and *Highway Drainage Guidelines* and other policy manuals. Highway agencies should consider these policies if they are not covered in their own guidelines.

For more details on this and other countermeasures: http://safety.transportation.org

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Provide Skid Resistance in Intersection and on Approaches

WHERE TO USE

Signalized intersection approaches where skidding is determined to be a problem, especially in wet conditions.

Photo by: Unknown

The surface friction of this intersection is being improved.

DETAILS

Slippery pavement should be addressed to reduce the potential for skidding. The coefficient of friction is most influenced by vehicle speed, vehicle tire condition, and pavement surface condition. Consideration should be given to improving the pavement condition to provide good skid resistance, especially during wet weather. This can be accomplished by:

- providing adequate drainage,
- grooving existing pavement, and
- overlaying existing pavement.

KEY TO SUCCESS

Monitoring the skid resistance of pavement requires incremental checks of pavement conditions. Evaluation must identify ruts and the occurrence of polishing. Recent research has suggested that the surface should be restored between 5 and 10 years in order to retain surface friction, but the life span is affected by site characteristics, such as traffic volume.

ISSUES

Skid resistance changes over time. This requires a dynamic program and strong commitment. It also requires good "targeting." When selecting sites for skid resistance programs, it is important to somehow control for the amount of wet-pavement exposure. This will help decrease the identification of sites that have a high wet-accident proportion or that rate simply because of high wet-weather exposure with no real pavement-friction problems. Unfortunately, it is difficult or impossible for an agency to develop good wet-pavement crash rates per vehicle mile for all roadway sections due

to the lack of good wet-weather exposure data for all sites. In its Skid Accident Reduction Program (SKARP), the New York State Department of Transportation (DOT) uses a surrogate for such detailed data. The DOT compares the proportion of wet-weather crashes at each site with the proportion for similar roads in the same county.

TIME FRAME ●●○

The time frame depends upon the treatment. Grooving can be done quickly, but overlays require more time. Nevertheless, all strategies being suggested should have short implementation periods.

COSTS ●●○○

Costs are highly variable, depending upon the specific treatment. The New York State DOT estimates that its resurfacing/microsurfacing projects are approximately 0.5 miles long, with an average treatment cost of approximately $20,000 per lane mile (1995 dollars).

EFFECTIVENESS

TRIED: The effectiveness of the countermeasure not only depends on the measure selected, but also varies with respect to location, traffic volume, rainfall propensity, road geometry, temperature, pavement structure, etc.

The New York State DOT has implemented a program that identifies sites statewide that have a low skid resistance and treats them with overlays or microsurfacing as part of the maintenance program. Between 1995 and 1997, 36 sites were treated on Long Island, resulting in a reduction of more than 800 annually recurring wet-road crashes. These results and others within the state support earlier findings that treatment of wet-road crash locations result in reductions of 50% for wet-road crashes and 20% for total crashes. While the reductions in run-off-road or head-on crashes cannot be extracted from the data at this time, it appears that reductions in these types would be at least the same as for total crashes.

While these results could be subject to some regression-to-the-mean bias, the New York staff has found that untreated sites continue to stay on the listing until treated in many cases—an indication that these reductions are clearly not totally due to regression.

COMPATIBILITY

Providing skid resistance is compatible with most other strategies to improve safety at signalized intersections.

SUPPLEMENTAL INFORMATION

Policy may be needed in order to determine the most appropriate pavement aggregate statewide and at special locations. Additionally, guidelines may be needed to highlight when pavement groove cuts should be considered. These countermeasures may also require cooperation within an agency, especially if these types of safety treatments are to be tied to routine maintenance.

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Coordinate Closely Spaced Signals near At-Grade Railroad Crossings

WHERE TO USE

Signalized intersections in close proximity to at-grade railroad crossings with a high frequency of crashes. This situation presents a significant potential for vehicle-train crashes, but vehicle-vehicle crashes could also occur if drivers try to speed through an intersection to avoid waiting in a queue near the railroad crossing.

Photo by: Texas Transportation Institute

DETAILS

At-grade railroad crossings on approaches to intersections have potential safety problems related to vehicle queues forming across the railroad tracks. The railroad and nearby traffic control signals should be coordinated to provide preemption of the traffic signals when trains are approaching the intersection.

KEY TO SUCCESS

A key to success is the compatibility of the traffic signal and railroad active warning devices in order to safely control vehicle, train, bicycle, and pedestrian movements. Vehicles must be provided with adequate green time to clear the railroad tracks when a train is approaching. This means that potential queue lengths during congested periods must be considered and train detection systems provided on the railroad tracks far enough upstream of the crossing for the signal preemption to clear all vehicles. A gate is an integral part of the active warning system.

ISSUES

The *Manual on Uniform Traffic Control Devices* states that warning lights shall flash for at least 20 seconds before a train approaches (for train speeds of 20 miles per hour or more). Train detection may need to occur earlier than when the train is 20 seconds away from the crossing, depending upon the amount of time needed to preempt the nearby signal and clear the tracks.

The railroad tracks may be so close to the intersection that a design vehicle cannot fit between the tracks and the intersection if it has to stop for a red signal. A pre-signal can be used to control traffic approaching the at-grade crossing. Pre-signals are installed on the near side of an at-grade railroad crossing, upstream of the traffic signal. The pre-signal turns red as a train approaches; this will occur before the downstream traffic signal turns red in order to allow vehicles to clear the railroad tracks. Care must be taken that a driver with a red pre-signal does not mistakenly think the green track clearance signal at the intersection is his or her signal. A special design of the signal face may be needed to ensure vehicles approaching the tracks do not misunderstand the signals.

Traffic engineers should communicate with railroad agencies to verify that the signal preemption system being designed is compatible with the railroad signal systems. Often there are problems with differences in terminology between various agencies (such as "preemption"), and care should be taken to clarify terminology.

TIME FRAME ●●○

Implementation time can vary, depending upon the communication and coordination among railway, highway, and any other agencies that would be involved in improvement of signal control at and near railroad grade crossings.

COSTS ●●○○

Costs involved in improving signal control near at-grade crossings can vary, depending upon the compatibility of existing equipment with the desired treatment. Installation of new equipment that allows coordination of signals will increase costs. Maintenance is another cost element to be considered.

EFFECTIVENESS

TRIED: Coordination of signals to clear the tracks when a train is approaching should eliminate the potential for vehicles to be trapped on the tracks.

COMPATIBILITY

Coordination of traffic signals with train detection and warning systems is compatible with most other strategies to improve signalized intersection safety.

SUPPLEMENTAL INFORMATION

A traffic signal preemption system should be designed considering many geometric, traffic flow, and vehicle and train characteristics. The Institute of Transportation Engineer's document entitled *Preemption of Traffic Signals at or near Railroad Grade Crossings with Active Warning Devices* contains discussion of these items.

Additional information can be found in *NCHRP Synthesis 271: Traffic Signal Operation near Highway-Grade Crossings*, including discussion of traffic signal and train detection systems.

For more details on this and other countermeasures: http://safety.transportation.org

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Relocate Signal Hardware out of Clear Zone

WHERE TO USE

Signalized intersections where signal hardware is located within the clear zone or is a sight obstruction (particularly on high-speed approaches).

Photo by: Texas Transportation Institute

DETAILS

Traffic signal hardware represents a potential roadside hazard similar to utility poles, trees, and other large fixed objects. Traffic signal supports and controller cabinets should be located as far from the edge of the pavement as possible, especially on high-speed facilities, as long as this does not adversely affect visibility of the signal indications. Consideration should be given to shielding the signal hardware if it cannot be relocated. Where there is an existing roadside barrier, the cabinet should be located behind the barrier when feasible. If practical, signal supports in medians should be located to provide more than the minimum clearance required by the agency. The signal hardware should not obstruct sight lines.

Post-mounted signals in the median of a road are often deemed appropriate to reinforce the information presented by the overhead signal heads at the intersection, especially at left-turn lanes, but can be a hazard in that location. However, if properly designed as breakaway structures, their benefit may outweigh the disadvantage of the location.

KEY TO SUCCESS

The new location of the signal hardware should not present a greater safety hazard than the previous location by creating a sight distance obstruction.

ISSUES

Care should be taken to ensure signal hardware is not relocated to a position where it obstructs sight distance or presents a safety hazard to pedestrians or bicyclists. The Americans with Disabilities Act should be consulted to ensure compliance.

TIME FRAME ●○○

Implementation time will be relatively short if additional right-of-way (ROW) is not needed in order to move the hardware outside the clear zone. Acquisition of ROW will increase implementation time.

COSTS ●●○○

Costs will be moderate if acquisition of ROW is not required to move the hardware outside the clear zone. Acquisition of ROW will increase costs.

EFFECTIVENESS

TRIED: Relocating the signal hardware outside the clear zone should reduce the likelihood of vehicles striking the hazard. The effectiveness of this strategy is difficult to estimate given the range of conditions and relative infrequency of such conflicts at any one location.

COMPATIBILITY

Relocation of signal hardware is compatible with most other strategies to improve safety at signalized intersections.

SUPPLEMENTAL INFORMATION

Highway agencies should review their traffic engineering and design policies regarding the clear zone and location of signal hardware to ensure appropriate actions are being taken on routine projects.

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Restrict or Eliminate Parking on Intersection Approaches

WHERE TO USE

Signalized intersections with permitted parking on the approaches that may present a safety hazard either by blocking sight distance or due to parking maneuvers.

Photo by: FHWA

DETAILS

Parking adjacent to turning and/or through lanes on intersection approaches may create a hazard. It can cause a frictional effect on the through traffic stream, can often block the sight triangle of stopped vehicles, and may occasionally cause the blocking of traffic lanes as vehicles move into and out of parking spaces. Restricting and/or eliminating parking on intersection approaches can reduce the workload imposed on the driver and limit additional collision opportunities. Parking restrictions can be implemented through signing, pavement markings, or restrictive channelization. Restrictions can be implemented for specific times of day or specific vehicle types. Enforcement of parking restrictions, accompanied by public information, including towing offending vehicles, is a necessary component of this strategy.

KEY TO SUCCESS

Parking regulation signs need to be posted conspicuously. Consistent and rigorous enforcement of these regulations is necessary as well. Working with owners of adjacent properties to communicate the reasons for prohibiting parking is also essential to achieving success.

ISSUES

The Uniform Vehicle Code does not require use of No Parking signs in some circumstances. Drivers are often not aware of some of the locations where parking is prohibited, however, and signs should be used to convey this information to drivers.

Adjacent land owners, particularly commercial businesses, may be opposed to the removal of on-street parking.

Removal of parking requires a commitment to enforcement through ticketing and towing where needed.

TIME FRAME ●○○

Time to implement parking restrictions is low if no new ordinances are required. Implementation may, however, require passing of ordinances by city councils.

COSTS ●○○○

Costs to implement parking restrictions with signing are low. If enforcement is used to help implement the restrictions, costs will be increased.

EFFECTIVENESS

TRIED: The Institute of Transportation Engineer's *Traffic Engineering Handbook* states that, based upon a review of crash data, 20% of non-freeway crashes in cities are in one way or another related to parking. Mid-block crash rates on major streets with parking stalls that are used about 1.0 million hours per year per mile could be expected to decrease up to 75% after parking is prohibited.

An Australian study showed that banning parking adjacent to an intersection resulted in an average decrease in crashes of 10%. ITE reports a 49% decrease in all crashes when parking is restricted near an intersection.

COMPATIBILITY

Restriction of parking is compatible with most other strategies for improving signalized intersection safety.

SUPPLEMENTAL INFORMATION

Highway agencies should review their traffic engineering and design policies regarding on-street parking to ensure appropriate action is being taken on projects. All stakeholders should be involved from the earliest stages of planning, including owners of adjacent properties and representatives of legislative bodies for the jurisdictions involved.

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