VOLUME 5

NCHRP

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

REPORT 500

Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

Volume 5: A Guide for Addressing Unsignalized Intersection Collisions



TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

Volume 5: A Guide for Addressing Unsignalized Intersection Collisions

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SUBJECT AREAS
Safety and Human Performance

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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FOREWORD

By Charles W. Niessner
Staff Officer
Transportation Research Board

The goal of the AASHTO Strategic Highway Safety Plan is to reduce annual highway fatalities by 5,000 to 7,000. This goal can be achieved through the widespread application of low-cost, proven countermeasures that reduce the number of crashes on the nation's highways. This fifth volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* provides strategies that can be employed to reduce the number of unsignalized intersection collisions. The report will be of particular interest to safety practitioners with responsibility for implementing programs to reduce injuries and fatalities on the highway system.

In 1998, AASHTO approved its Strategic Highway Safety Plan, which was developed by the AASHTO Standing Committee for Highway Traffic Safety with the assistance of the Federal Highway Administration, the National Highway Traffic Safety Administration, and the Transportation Research Board Committee on Transportation Safety Management. The plan includes strategies in 22 key emphasis areas that affect highway safety. The plan's goal is to reduce the annual number of highway deaths by 5,000 to 7,000. Each of the 22 emphasis areas includes strategies and an outline of what is needed to implement each strategy.

NCHRP Project 17-18(3) is developing a series of guides to assist state and local agencies in reducing injuries and fatalities in targeted areas. The guides correspond to the emphasis areas outlined in the AASHTO Strategic Highway Safety Plan. Each guide includes a brief introduction, a general description of the problem, the strategies/countermeasures to address the problem, and a model implementation process.

This is the fifth volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*, a series in which relevant information is assembled into single concise volumes, each pertaining to specific types of highway crashes (e.g., run-off-the-road, head-on) or contributing factors (e.g., aggressive driving). An expanded version of each volume, with additional reference material and links to other information sources, is available on the AASHTO Web site at http://transportation1.org/safetyplan. Future volumes of the report will be published and linked to the Web site as they are completed.

While each volume includes countermeasures for dealing with particular crash emphasis areas, *NCHRP Report 501: Integrated Management Process to Reduce Highway Injuries and Fatalities Statewide* provides an overall framework for coordinating a safety program. The integrated management process comprises the necessary steps for advancing from crash data to integrated action plans. The process includes methodologies to aid the practitioner in problem identification, resource optimization, and performance measurements. Together, the management process and the guides provide a comprehensive set of tools for managing a coordinated highway safety program.

Contents

Acknowledgments

This series of six implementation guides was developed under NCHRP Project 17-18(3). The project was managed by CH2M HILL. The co-principal investigators were Ron Pfefer of Maron Engineering and Kevin Slack of CH2M HILL. Timothy Neuman of CH2M HILL served as the overall project director for the CH2M HILL team. Kelly Kennedy Hardy, also of CH2M HILL, participated in development of the guides.

This phase of the project involved the development of guide books addressing six different emphasis areas of AASHTO's Strategic Highway Safety Plan. The project team was organized around the specialized technical content contained in each guide. The CH2M HILL team included nationally recognized experts from many organizations. The following team of experts, selected based on their knowledge and expertise in a particular emphasis area, served as lead authors for each of the guides.

- Forrest Council of BMI led the development of "A Guide for Addressing Run-Off-Road Collisions"
- Doug Harwood of Midwest Research Institute led the development of "A Guide for Addressing Unsignalized Intersection Collisions"
- Hugh McGee of BMI led the development of "A Guide for Addressing Head-On Collisions"
- Richard Raub of Northwestern University Center for Public Safety led the development of "A Guide for Addressing Aggressive-Driving Collisions"
- Patricia Waller led the development of "A Guide for Addressing Collisions Involving Unlicensed Drivers and Drivers with Suspended or Revoked Licenses"
- Charlie Zegeer and Kevin Lacy of University of North Carolina Highway Safety Research Center led the development of "A Guide for Addressing Collisions Involving Trees in Hazardous Locations"

Development of the guides utilized the resources and expertise of many professionals from around the country and overseas. Through research, workshops, and actual demonstration of the guides by agencies, the resulting document represents best practices in each emphasis area. The project team is grateful to the following list of people and their agencies for their input on the guides and their support of the project:

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A Guide for Addressing Unsignalized Intersection Collisions

This guide was developed in NCHRP Project 17-18(3) as part of an ongoing effort to implement the AASHTO Strategic Highway Safety Plan and achieve a significant reduction in highway crash fatalities at unsignalized intersections. The guide was prepared by Mr. Douglas W. Harwood, Ms. Ingrid B. Potts, Dr. Emilia Kohlman Rabbani, and Dr. Darren J. Torbic at Midwest Research Institute. The authors wish to thank the following state highway agency representatives (and members of their teams) who provided material, input, and comments during the development of this guide:

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SECTION I

Summary

Introduction

One of the hallmarks of the American Association of State Highway and Transportation Officials (AASHTO) Strategic Highway Safety Plan (SHSP) is to comprehensively approach safety problems. The range of strategies available in the guides will ultimately cover various aspects of the road user, the highway, the vehicle, the environment, and the management system. The guides strongly encourage the user to develop a program to tackle a particular emphasis area from each of these perspectives in a coordinated manner. To facilitate this coordination, hypertext linkages are provided on AASHTO's Web site at http://transportation1.org/safetyplan to allow for seamless integration of various approaches to a given problem. As more guides are developed for other emphasis areas, the extent and usefulness of this form of implementation will become more apparent.

The goal is to move away from *independent* activities of engineers, law enforcement, educators, judges, and other highway safety specialists. The implementation process outlined in the guides promotes forming working groups and alliances that represent all of the elements of the safety system. In this formation, highway safety specialists can use their combined expertise to reach the bottom-line goal of targeted reduction of crashes and fatalities associated with a particular emphasis area.

The six major areas of the AASHTO SHSP (Drivers, Vehicles, Special Users, Highways, Emergency Medical Services, and Management) are subdivided into 22 goals, or key emphasis areas, that impact highway safety. One of these goals addresses the improvement of safety at intersections. A key to improving intersection safety is to address safety problems at unsignalized intersections. This implementation guide provides guidance to highway agencies that want to implement safety improvements at unsignalized intersections and includes a variety of strategies that may be applicable to particular locations.

Intersections are locations where two or more roads join or cross one another. The crossing and turning maneuvers that occur at intersections create opportunities for vehicle-vehicle, vehicle-pedestrian, and vehicle-bicycle conflicts, which may result in traffic crashes. Thus, intersections are likely points for concentrations of traffic crashes. Unsignalized intersections are of particular concern because there are so many of them on the U.S. highway system and because some experience sufficient numbers of particular crash types to indicate a need to improve safety.

Unsignalized intersections represent potential hazards not present at signalized intersections because of the priority of movement on the main road. Vehicles stopping or slowing to turn create speed differentials between vehicles traveling in the same direction. This is particularly problematic on two-lane highways. The intersections along low- to moderate-volume roads in rural and suburban areas are usually unsignalized. These roadways are generally associated with high-speed travel and relatively lower geometrics than those in more developed suburban and urban areas.

General Description of Problem

Intersections constitute only a small part of the overall highway system, yet intersection-related crashes constitute more than 50 percent of all crashes in urban areas and over 30 percent in rural areas (Kuciemba and Cirillo, 1992). Fatal intersection crashes are a smaller portion of the total picture, suggesting that severity of crashes at intersections is lower than elsewhere (Exhibit I-1).

Exhibit I-2 shows the severity of crashes at unsignalized intersections as estimated for the United States in 1999 by the National Center for Statistics and Analysis (NCSA) General Estimates System (GES), operated by NHTSA.

EXHIBIT I-1
Fatal Crashes by Location

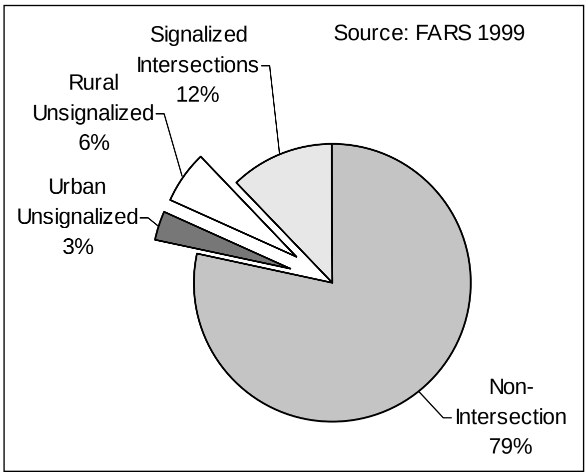
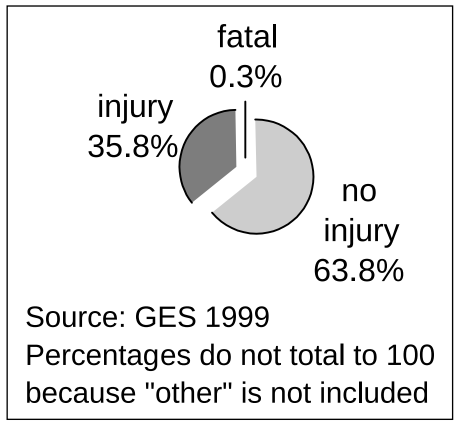


EXHIBIT I-2
Severity of Accidents at Unsignalized Intersections



It is not unusual that crashes are concentrated at intersections, because intersections are the point on the roadway system where traffic movements most frequently conflict with one another. Good geometric design combined with good traffic control can result in an efficient and safe intersection.

A recent analysis of California data found that an average of 1.5 crashes per year occur at unsignalized intersections in rural areas, compared with 2.5 crashes per year in urban areas (Bauer and Harwood, 1996). By contrast, urban signalized intersections averaged 4.6 crashes per year. However, these values are average—many intersections have substantially higher crash frequencies, and these higher frequencies are the appropriate targets for improvements. There are many more unsignalized intersections than signalized, so the number of crashes is undoubtedly much higher at unsignalized intersections nationwide than at signalized intersections.

As population and development increases, traffic at unsignalized intersections grows, as does traffic volume and the number of crashes. There is increasing demand for signalization of urban and suburban intersections, and, even in rural areas, signalized intersections are becoming more common. However, experience shows that intersection crash rates frequently increase with signal installation, although the crashes may be less severe. Signalization usually leads to a shift in crash types, with fewer angle and turning collisions and more rear-end collisions.

Objectives of the Emphasis Area

The objectives for improving safety at unsignalized intersections are explained below. Exhibit I-3 lists the objectives and strategies for improving safety at unsignalized intersections. Most of the objectives concern the physical improvement of unsignalized intersections and their approaches, while others relate to driver compliance. The strategies considered go across the full range of engineering, enforcement, and education. The physical improvements considered include both geometric design modifications and changes to traffic control devices:

- Improve management of access near unsignalized intersections—Driveway access at or near an unsignalized intersection may confuse drivers using the intersection and create vehicle-vehicle conflicts. For good access management, driveways within 250 feet of an intersection should be closed, relocated, or restricted.
- Reduce the frequency and severity of intersection conflicts through geometric design improvements—Reducing the frequency and severity of vehicle-vehicle conflicts at intersections can reduce the frequency and severity of intersection crashes. This can be accomplished by separating through and turning movements at the intersection, restricting or eliminating turning maneuvers, providing acceleration lanes, and closing or relocating intersections.
- Improve sight distance at unsignalized intersections—Some collisions at unsignalized intersections occur because of limited sight distance for drivers approaching the intersection or for drivers stopped at an intersection approach. Provision of clear sight triangles in each quadrant of an intersection can minimize the possibility of crashes related to sight obstructions.
- Improve availability of gaps in traffic and assist drivers in judging gap sizes at unsignalized intersections—Some collisions at unsignalized intersections occur because drivers have difficulty judging gap sizes before deciding whether to initiate a roadway entry or a turning maneuver. Drivers stopped to wait for the oncoming traffic stream often choose to proceed when oncoming vehicles are close, thus increasing the probability for a collision.
- Improve driver awareness of intersections as viewed from the intersection approach—Some intersection-related collisions occur because one or more drivers approaching an intersection are unaware of the intersection until it is too late to avoid a collision. This is a particular problem for drivers approaching unsignalized intersections on high-speed uncontrolled approaches. Improved signing and delineation and installation of lighting can help warn drivers of the presence of the intersection. In some situations where other measures have not been effective, rumble strips may be used to get the driver's attention.
- Choose appropriate intersection traffic control to minimize crash frequency and severity—The type of traffic control chosen for an intersection has a strong influence on the frequency and severity of crashes that occur at the intersection. The type of traffic control should be appropriate for the configuration of the intersection and the traffic volumes to be served. Unsignalized intersections generally have fewer crashes than comparable signalized intersections, so signalization should be avoided where practical. Alternatives to signalization that should be considered are two-way stop control (with or without flashing beacons), all-way stop control (with or without flashing beacons), and roundabouts.

- Improve driver compliance with traffic control devices and traffic laws at intersections—Many accidents are caused by noncompliance with traffic control devices or traffic laws at intersections. Enforcement has been shown to be an effective measure in reducing traffic-law violations and, consequently, in improving safety at intersections.
- Reduce operating speeds on specific intersection approaches—At certain high-speed intersection approaches, implementing speed-reduction measures may provide an approaching driver with additional time to make safer and more efficient intersection-related decisions. The speed-reduction measure will get the driver's attention and prepare the driver for making a stop or other appropriate action, thus potentially reducing right-angle and rear-end collisions.
- Guide motorists more effectively through complex intersections—As drivers approach and traverse through complex intersections, drivers may be required to perform unusual or unexpected maneuvers. Providing more effective guidance through the intersection, through the use of signing and pavement markers, will minimize the likelihood of a vehicle leaving its appropriate lane and encroaching upon an adjacent lane. The additional guidance will also minimize indecision by drivers, thus reducing the potential for conflicts.

EXHIBIT I-3
Objectives and Strategies for Improving Safety at Unsignalized Intersections

Objectives	Strategies
17.1 A—Improve management of access near unsignalized intersections	17.1 A1—Implement driveway closures/relocations (T)*
	17.1 A2—Implement driveway turn restrictions (T)
17.1 B—Reduce the frequency and severity of intersection conflicts through geometric design improvements	17.1 B1—Provide left-turn lanes at intersections (P)
	17.1 B2—Provide longer left-turn lanes at intersections (T)
	17.1 B3—Provide offset left-turn lanes at intersections (T)
	17.1 B4—Provide bypass lanes on shoulders at T-intersections (T)
	17.1 B5—Provide left-turn acceleration lanes at divided highway intersections (T)
	17.1 B6—Provide right-turn lanes at intersections (P)
	17.1 B7—Provide longer right-turn lanes at intersections (T)
	17.1 B8—Provide offset right-turn lanes at intersections (T)
	17.1 B9—Provide right-turn acceleration lanes at intersections (T)
	17.1 B10—Provide full-width paved shoulders in intersection areas (T)
	17.1 B11—Restrict or eliminate turning maneuvers by signing (T)
	17.1 B12—Restrict or eliminate turning maneuvers by providing channelization or closing median openings (T)
	17.1 B13—Close or relocate "high-risk" intersections (T)

EXHIBIT I-3 (Continued)
Objectives and Strategies for Improving Safety at Unsignalized Intersections

Objectives	Strategies
	17.1 B14—Convert four-legged intersections to two T-intersections (T)
	17.1 B15—Convert offset T-intersections to four-legged intersections (T)
	17.1 B16—Realign intersection approaches to reduce or eliminate intersection skew (P)
	17.1 B17—Use indirect left-turn treatments to minimize conflicts at divided highway intersections (T)
	17.1 B18—Improve pedestrian and bicycle facilities to reduce conflicts between motorists and nonmotorists (varies)
17.1 C—Improve sight distance at unsignalized intersections	17.1 C1—Clear sight triangles on stop- or yield-controlled approaches to intersections (T)
	17.1 C2—Clear sight triangles in the medians of divided highways near intersections (T)
	17.1 C3—Change horizontal and/or vertical alignment of approaches to provide more sight distance (T)
	17.1 C4—Eliminate parking that restricts sight distance (T)
17.1 D—Improve availability of gaps in traffic and assist drivers in judging gap sizes at unsignalized intersections	17.1 D1—Provide an automated real-time system to inform drivers of the suitability of available gaps for making turning and crossing maneuvers (E)
	17.1 D2—Provide roadside markers or pavement markings to assist drivers in judging the suitability of available gaps for making turning and crossing maneuvers (E)
	17.1 D3—Retime adjacent signals to create gaps at stop-controlled intersections (T)
17.1 E—Improve driver awareness of intersections as viewed from the intersection approach	17.1 E1—Improve visibility of intersections by providing enhanced signing and delineation (T)
	17.1 E2—Improve visibility of the intersection by providing lighting (P)
	17.1 E3—Install splitter islands on the minor-road approach to an intersection (T)
	17.1 E4—Provide a stop bar (or provide a wider stop bar) on minor-road approaches (T)
	17.1 E5—Install larger regulatory and warning signs at intersections (T)
	17.1 E6—Call attention to the intersection by installing rumble strips on intersection approaches (T)
	17.1 E7—Provide dashed markings (extended left edgelines) for major-road continuity across the median opening at divided highway intersections (T)
	17.1 E8—Provide supplementary stop signs mounted over the roadway (T)

(*continued on next page*)

EXHIBIT I-3 (Continued)
Objectives and Strategies for Improving Safety at Unsignalized Intersections

Objectives	Strategies
	17.1 E9—Provide pavement markings with supplementary messages, such as STOP AHEAD (T)
	17.1 E10—Provide improved maintenance of stop signs (T)
	17.1 E11—Install flashing beacons at stop-controlled intersections (T)
17.1 F—Choose appropriate intersection traffic control to minimize crash frequency and severity	17.1 F1—Avoid signalizing through roads (T)
	17.1 F2—Provide all-way stop-control at appropriate intersections (P)
	17.1 F3—Provide roundabouts at appropriate locations (P)
17.1 G—Improve driver compliance with traffic control devices and traffic laws at intersections	17.1 G1—Provide targeted enforcement to reduce stop sign violations (T)
	17.1 G2—Provide targeted public information and education on safety problems at specific intersections (T)
17.1 H—Reduce operating speeds on specific intersection approaches	17.1 H1—Provide targeted speed enforcement (P)
	17.1 H2—Provide traffic calming on intersection approaches through a combination of geometrics and traffic control devices (P)
	17.1 H3—Post appropriate speed limit on intersection approaches (T)
17.1 I—Guide motorists more effectively through complex intersections	17.1 I1—Provide turn path markings (T)
	17.1 I2—Provide a double yellow centerline on the median opening of a divided highway at intersections (T)
	17.1 I3—Provide lane assignment signing or marking at complex intersections (T)

*See pages V–4 and V–5 for an explanation of “E,” “P,” and “T” designations.

SECTION II

Introduction

One of the hallmarks of the AASHTO SHSP is to approach safety problems comprehensively. The range of strategies available in the guides will ultimately cover various aspects of the road user, the highway, the vehicle, the environment, and the management system. The guides strongly encourage the user to develop a program to tackle a particular emphasis area from each of these perspectives in a coordinated manner. To facilitate this development, hypertext linkages are provided in the electronic version of this document to allow seamless integration of various approaches to a given problem. As more guides are developed for other emphasis areas, the extent and usefulness of this form of implementation will become more apparent.

The goal is to move away from *independent* activities of engineers, law enforcement, educators, judges, and other highway-safety specialists. The implementation process outlined in the guides promotes forming working groups and alliances that represent all of the elements of the safety system. In so doing, the groups can use the combined expertise of their members to reach the bottom-line goal of targeted reduction of crashes and fatalities associated with a particular emphasis area.

In addition, many of the design principles to be applied to improve intersection safety require knowledge of human factors. Not only should specialists in this area be involved, but training for design engineers should include the application of human-factors principles.

The six major areas of the AASHTO SHSP (Drivers, Vehicles, Special Users, Highways, Emergency Medical Services, and Management) are subdivided into 22 goals, or key emphasis areas, that impact highway safety. One of these goals addresses the improvement of safety at intersections. A key to improving intersection safety is to address safety problems at unsignalized intersections. This implementation guide provides guidance to highway agencies that want to implement safety improvements at unsignalized intersections and includes a variety of strategies that may be applicable to particular locations.

Intersections are locations where two or more roads join or cross one another. The crossing and turning maneuvers that occur at intersections create opportunities for vehicle-vehicle, vehicle-pedestrian, and vehicle-bicycle conflicts, which may result in traffic crashes. Thus, intersections are likely points for concentrations of traffic crashes. Unsignalized intersections are of particular concern because there are so many of them on the U.S. highway system and because some experience sufficient numbers of particular crash types, indicating a need to improve safety.

Unsignalized intersections represent potential hazards not present at signalized intersections because of the priority of movement on the main road. Vehicles stopping or slowing to turn create speed differentials between vehicles traveling in the same direction. This is particularly problematic on two-lane highways. The intersections along low- to moderate-volume roads in rural and suburban areas are usually unsignalized. These roadways are generally associated with high-speed travel and relatively lower geometrics than those in more developed suburban and urban areas.

SECTION III

The Type of Problem Being Addressed

General Description of Problem

Intersections constitute only a small part of the overall highway system, yet intersection-related crashes constitute more than 50 percent of all crashes in urban areas and over 30 percent in rural areas (Kuciemba and Cirillo, 1992). Fatal intersection crashes are a smaller portion of the total picture, suggesting that severity of crashes at intersections is lower than elsewhere (Exhibit III-1).

Exhibit III-2 shows the severity of crashes at unsignalized intersections as estimated for the United States in 1999 by the NCSA GES, operated by NHTSA.

EXHIBIT III-1
Fatal Crashes by Location

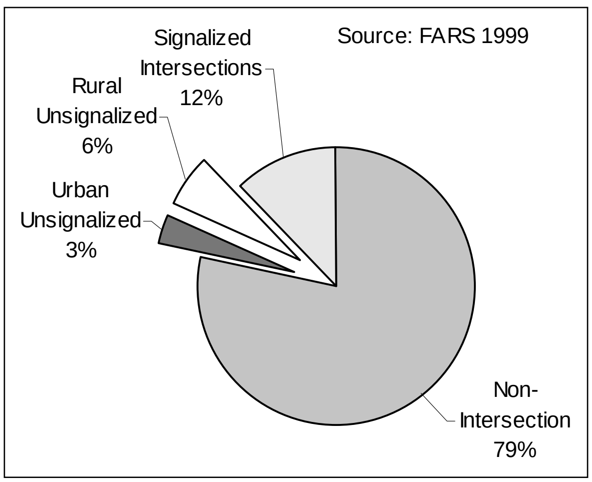
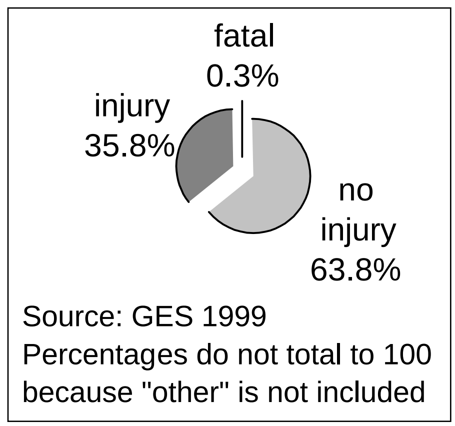


EXHIBIT III-2
Severity of Accidents at Unsignalized Intersections



It is not unusual that crashes are concentrated at intersections, because intersections are the point on the roadway system where traffic movements most frequently conflict with one another. Good geometric design combined with good traffic control can result in an efficient and safe intersection.

A recent analysis of California data found that, on average, 1.5 crashes per year occur at unsignalized intersections in rural areas, compared with 2.5 crashes per year in urban areas (Bauer and Harwood, 1996). By contrast, urban signalized intersections averaged 4.6 crashes per year. However, these values are average—many intersections have substantially higher crash frequencies, and these higher frequencies are the appropriate targets for improvements. There are many more unsignalized intersections than signalized, so the number of crashes is undoubtedly much higher at unsignalized intersections nationwide than at signalized intersections.

As population and development increases, traffic at unsignalized intersections grows, as does traffic volume and the number of crashes. There is increasing demand for signalization of urban and suburban intersections, and, even in rural areas, signalized intersections are becoming more common. However, experience shows that intersection crash rates frequently increase with signal installation, although the crashes may be less severe. Signalization usually leads to a shift in crash types, with fewer angle and turning collisions and more rear-end collisions.

Specific Attributes of the Problem

Exhibit III-3 depicts the distribution of fatal crashes by manner of collision. It shows the preponderance of angle crashes, and the significant role of crashes with fixed objects. Angle crashes include a large proportion of turning vehicles, especially left turns.

Exhibit III-4 shows that the first harmful event is primarily collision with another motor vehicle. However, there is a significant number of collisions with fixed objects and other non-fixed objects, including pedestrians and bicyclists.

Other specific attributes of safety problems at unsignalized intersections include

- Diverse geometric design and traffic control features of intersections;
- Diverse vehicle population, including a wide range of vehicle sizes and weights;
- Diverse driver populations, including anticipated demographic changes;
- Climate-related problems, such as wet and ice-and-snow-covered pavements; and
- Wide range of traffic volumes on intersection approaches, with patterns of daily and seasonal variations.

Of these attributes, only geometric design and traffic control features are under the direct control of highway agencies. Aspects of problems related to other driver and vehicle issues are addressed in other parts of the AASHTO SHSP that are not specific to unsignalized intersections.

EXHIBIT III-3
Manner of Collision for Fatal Crashes at Unsignalized Intersections

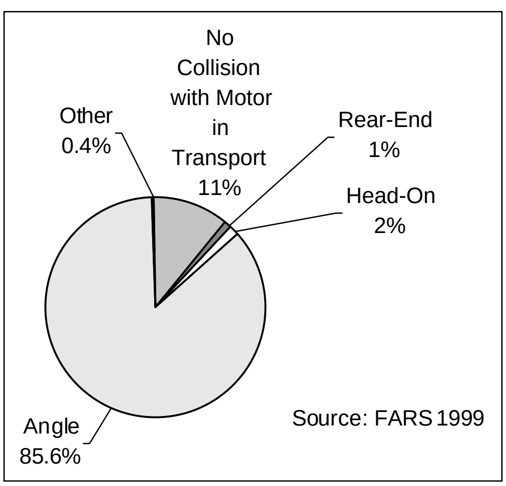
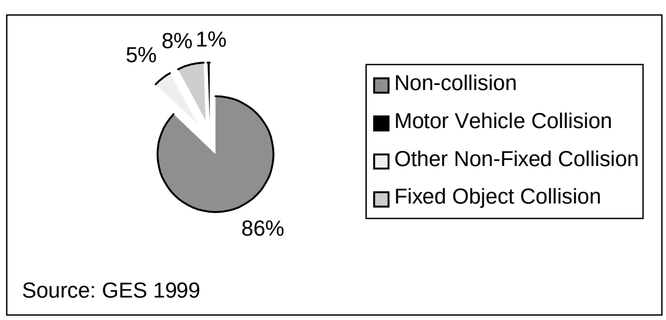


EXHIBIT III-4
1999 Unsignalized Intersection Accidents First Harmful Event



SECTION IV

Index of Strategies by Implementation Timeframe and Relative Cost

Exhibit IV-1 provides a classification of strategies according to the expected timeframe and relative cost for this emphasis area. In several cases, the implementation time will be dependent upon such factors as the agency's procedures, the need for additional right-of-way, the number of stakeholders involved, and the presence of any controversial situations. The range of costs may also be somewhat variable for some of these strategies because of many of the same factors. Placement in the table below is meant to reflect costs relative to the other strategies listed for this emphasis area only. The estimated level of cost is for the commonly expected application of the strategy, especially one that does not involve additional right-of-way, or major construction, unless it is an inherent part of the strategy.

EXHIBIT IV-1
Index of Strategies by Implementation Timeframe and Relative Cost

Timeframe for Implementation		Relative Cost to Implement and Operate			
		Low	Moderate	Moderate to High	High
Short (less than a year)	17.1 A2—Implement driveway turn restrictions	✓			
	17.1 B4—Provide bypass lanes on shoulders at T-intersections	✓			
	17.1 B11—Restrict or eliminate turning maneuvers by signing	✓			
	17.1 B12—Restrict or eliminate turning maneuvers by providing channelization or closing median openings	✓			
	17.1 C1—Clear sight triangles on stop- or yield-controlled approaches to intersections	✓			
	17.1 C2—Clear sight triangles in the medians of divided highways near intersections	✓			
	17.1 C4—Eliminate parking that restricts sight distance	✓			
	17.1 D3—Retime adjacent signals to create gaps at stop-controlled intersections	✓			

(*continued on next page*)

EXHIBIT IV-1 (Continued)
Index of Strategies by Implementation Timeframe and Relative Cost

Timeframe for Implementation		Relative Cost to Implement and Operate			
		Low	Moderate	Moderate to High	High
	17.1 E1—Improve visibility of intersections by providing enhanced signing and delineation	✓			
	17.1 E4—Provide a stop bar (or provide a wider stop bar) on minor-road approaches	✓			
	17.1 E5—Install larger regulatory and warning signs at intersections	✓			
	17.1 E6—Call attention to the intersection by installing rumble strips on intersection approaches	✓			
	17.1 E7—Provide dashed markings (extended left edgelines) for major roadway continuity at divided highway intersections	✓			
	17.1 E8—Provide supplementary stop signs mounted over the roadway	✓			
	17.1 E9—Provide pavement markings with supplementary messages, such as STOP AHEAD	✓			
	17.1 E10—Provide improved maintenance of stop signs	✓			
	17.1 E11—Install flashing beacons at stop-controlled intersections	✓			
	17.1 F2—Provide all-way stop control at appropriate intersections	✓			
	17.1 G1—Provide targeted enforcement to reduce stop sign violations		✓		
	17.1 G3—Provide targeted public information and education on safety problems at specific intersections	✓			
	17.1 H1—Provide targeted speed enforcement		✓		
	17.1 H3—Post appropriate speed limit on intersection approaches	✓			
	17.1 I1—Provide turn path markings	✓			
	17.1 I2—Provide a double yellow centerline on the median opening of a divided highway at intersections	✓			
	17.1 I3—Provide lane assignment signing or marking at complex intersections	✓			

EXHIBIT IV-1 (Continued)
Index of Strategies by Implementation Timeframe and Relative Cost

Timeframe for Implementation		Relative Cost to Implement and Operate			
		Low	Moderate	Moderate to High	High
Medium (1 to 2 years)	17.1 A1—Implement driveway closures/relocations		✓		
	17.1 B1—Provide left-turn lanes at intersections		✓		
	17.1 B2—Provide longer left-turn lanes at intersections		✓		
	17.1 B3—Provide offset left-turn lanes at intersections			✓	
	17.1 B5—Provide left-turn acceleration lanes at divided highway intersections		✓		
	17.1 B6—Provide right-turn lanes at intersections		✓		
	17.1 B7—Provide longer right-turn lanes at intersections		✓		
	17.1 B8—Provide offset right-turn lanes at intersections			✓	
	17.1 B9—Provide right-turn acceleration lanes at intersections		✓		
	17.1 B10—Provide full-width paved shoulders in intersection areas		✓		
	17.1 B14—Convert four-legged intersections to two T-intersections				✓
	17.1 B15—Convert offset T-intersections to four-legged intersections				✓
	17.1 B16—Realign intersection approaches to reduce or eliminate intersection skew				✓
	17.1 B17—Use indirect left-turn treatments to minimize conflicts at divided highway intersections		✓		
	17.1 B18—Improve pedestrian and bicycle facilities to reduce conflicts between motorists and nonmotorists[a]		✓		
	17.1 D1—Provide an automated real-time system to inform drivers of the suitability of available gaps for making turning and crossing maneuvers		✓		

(*continued on next page*)

EXHIBIT IV-1 (Continued)
Index of Strategies by Implementation Timeframe and Relative Cost

Timeframe for Implementation		Relative Cost to Implement and Operate: Low	Moderate	Moderate to High	High
	17.1 D2—Provide roadside markers or pavement markings to assist drivers in judging the suitability of available gaps for making turning and crossing maneuvers	✓			
	17.1 E2—Improve visibility of the intersection by providing lighting			✓	
	17.1 E3—Install splitter islands on the minor-road approach to an intersection		✓		
	17.1 H2—Provide traffic calming on intersection approaches through a combination of geometrics and traffic control devices		✓		
Long (more than 2 years)	17.1 B13—Close or relocate high-risk intersections				✓
	17.1 C3—Change horizontal and/or vertical alignment of approaches to provide more sight distance				✓
	17.1 F1—Avoid signalizing through roads[b]				✓
	17.1 F3—Provide roundabouts at appropriate locations				✓

[a]While there is expected to be wide variation of cost and time to implement for most of the strategies, this strategy is particularly subject to variation. The estimate shown is considered to be the middle of the range.

[b]While it is possible to install all-way stop control at relatively low cost and do so within a year, the strategy is classified to reflect the greater majority of options, which are costly and require a long time for design development and construction.

SECTION V

Description of Strategies

Objectives

The objectives for improving safety at unsignalized intersections are explained below. Exhibit V-1 lists the objectives and their strategies. Most of the objectives are directed at the physical improvement of unsignalized intersections and their approaches, whereas some relate to driver compliance. The improvements considered include geometric design modifications, changes to traffic control devices, targeted enforcement efforts, and public education. The objectives are as follows:

- **Improve management of access near unsignalized intersections—**Driveway access at or near an unsignalized intersection may confuse drivers using the intersection and create vehicle-vehicle conflicts. For good access management, driveways within 250 feet of an intersection should be closed, relocated, or restricted.
- **Reduce the frequency and severity of intersection conflicts through geometric design improvements—**Reducing the frequency and severity of vehicle-vehicle conflicts at intersections can reduce the frequency and severity of intersection crashes. This can be accomplished by separating through and turning movements at the intersection, restricting or eliminating turning maneuvers, providing acceleration lanes, and closing or relocating intersections.
- **Improve sight distance at unsignalized intersections—**Some collisions at unsignalized intersections occur because of limited sight distance for drivers who are approaching the intersection or who are stopped on an intersection approach. Provision of clear sight triangles in each quadrant of an intersection can minimize the possibility of crashes related to sight obstructions.
- **Improve availability of gaps in traffic and assist drivers in judging gap sizes at unsignalized intersections—**Some collisions at unsignalized intersections occur because drivers have difficulty judging gap sizes before deciding whether to initiate a roadway entry or a turning maneuver. Drivers stopped to wait for the oncoming traffic stream often choose to proceed when oncoming vehicles are close, thus increasing the probability for a collision.
- **Improve driver awareness of intersections as viewed from the intersection approach—** Some intersection-related collisions occur because one or more drivers approaching an intersection are unaware of the intersection until it is too late to avoid a collision. This is a particular problem for high-speed uncontrolled approaches. Improving signing and delineation and installing lighting can help warn drivers of the intersection. In some situations, where other measures have not been effective, rumble strips may be used to get the driver’s attention.
- **Choose appropriate intersection traffic control to minimize crash frequency and severity—**The type of traffic control chosen for an intersection has a strong influence on

the frequency and severity of crashes that occur at the intersection. The type of traffic control should be appropriate for the configuration of the intersection and the traffic volumes to be served. Unsignalized intersections generally have fewer crashes than comparable signalized intersections, so signalization should be avoided where practical. Alternatives to signalization that should be considered are two-way stop control (with or without flashing beacons), all-way stop control (with or without flashing beacons), and roundabouts.

- **Improve driver compliance with traffic control devices and traffic laws at intersections—**Many accidents are caused by noncompliance with traffic control devices or traffic laws at intersections. The use of enforcement has been shown to be an effective measure in reducing traffic-law violations and, consequently, in improving safety at intersections.
- **Reduce operating speeds on specific intersection approaches—**At certain high-speed intersection approaches, speed-reduction measures may provide an approaching driver with additional time to make safer and more efficient intersection-related decisions. The speed-reduction measure will get the driver's attention and prepare the driver for making a stop or other appropriate action, thus potentially reducing right-angle and rear-end collisions.
- **Guide motorists more effectively through complex intersections—**As drivers approach and traverse complex intersections, they may be required to perform unusual or unexpected maneuvers. Providing more-effective positive guidance through the intersection through signing and pavement markers will minimize the likelihood of a vehicle leaving its appropriate lane and encroaching upon an adjacent lane. The additional guidance will also minimize indecision by drivers, thus reducing the potential for conflicts.

EXHIBIT V-1
Objectives and Strategies for Improving Safety at Unsignalized Intersections

Objectives	Strategies
17.1 A—Improve management of access near unsignalized intersections	17.1 A1—Implement driveway closures/relocations (T)* 17.1 A2—Implement driveway turn restrictions (T)
17.1 B—Reduce the frequency and severity of intersection conflicts through geometric design improvements	17.1 B1—Provide left-turn lanes at intersections (P) 17.1 B2—Provide longer left-turn lanes at intersections (T) 17.1 B3—Provide offset left-turn lanes at intersections (T) 17.1 B4—Provide bypass lanes on shoulders at T-intersections (T) 17.1 B5—Provide left-turn acceleration lanes at divided highway intersections (T) 17.1 B6—Provide right-turn lanes at intersections (P) 17.1 B7—Provide longer right-turn lanes at intersections (T) 17.1 B8—Provide offset right-turn lanes at intersections (T)

EXHIBIT V-1 (Continued)
Objectives and Strategies for Improving Safety at Unsignalized Intersections

Objectives	Strategies
	17.1 B9—Provide right-turn acceleration lanes at intersections (T)
	17.1 B10—Provide full-width paved shoulders in intersection areas (T)
	17.1 B11—Restrict or eliminate turning maneuvers by signing (T)
	17.1 B12—Restrict or eliminate turning maneuvers by providing channelization or closing median openings (T)
	17.1 B13—Close or relocate “high-risk” intersections (T)
	17.1 B14—Convert four-legged intersections to two T-intersections (T)
	17.1 B15—Convert offset T-intersections to four-legged intersections (T)
	17.1 B16—Realign intersection approaches to reduce or eliminate intersection skew (P)
	17.1 B17—Use indirect left-turn treatments to minimize conflicts at divided highway intersections (T)
	17.1 B18—Improve pedestrian and bicycle facilities to reduce conflicts between motorists and nonmotorists (varies)
17.1 C—Improve sight distance at unsignalized intersections	17.1 C1—Clear sight triangles on stop- or yield-controlled approaches to intersections (T)
	17.1 C2—Clear sight triangles in the medians of divided highways near intersections (T)
	17.1 C3—Change horizontal and/or vertical alignment of approaches to provide more sight distance (T)
	17.1 C4—Eliminate parking that restricts sight distance (T)
17.1 D—Improve availability of gaps in traffic and assist drivers in judging gap sizes at unsignalized intersections	17.1 D1—Provide an automated real-time system to inform drivers of the suitability of available gaps for making turning and crossing maneuvers (E)
	17.1 D2—Provide roadside markers or pavement markings to assist drivers in judging the suitability of available gaps for making turning and crossing maneuvers (E)
	17.1 D3—Retime adjacent signals to create gaps at stop-controlled intersections (T)
17.1 E—Improve driver awareness of intersections as viewed from the intersection approach	17.1 E1—Improve visibility of intersections by providing enhanced signing and delineation (T)
	17.1 E2—Improve visibility of the intersection by providing lighting (P)
	17.1 E3—Install splitter islands on the minor-road approach to an intersection (T)
	17.1 E4—Provide a stop bar (or provide a wider stop bar) on minor-road approaches (T)
	17.1 E5—Install larger regulatory and warning signs at intersections (T)

(*continued on next page*)

EXHIBIT V-1 (Continued)
Objectives and Strategies for Improving Safety at Unsignalized Intersections

Objectives	Strategies
	17.1 E6—Call attention to the intersection by installing rumble strips on intersection approaches (T)
	17.1 E7—Provide dashed markings (extended left edgelines) for major-road continuity across the median opening at divided highway intersections (T)
	17.1 E8—Provide supplementary stop signs mounted over the roadway (T)
	17.1 E9—Provide pavement markings with supplementary messages, such as STOP AHEAD (T)
	17.1 E10—Provide improved maintenance of stop signs (T)
	17.1 E11—Install flashing beacons at stop-controlled intersections (T)
17.1 F—Choose appropriate intersection traffic control to minimize crash frequency and severity	17.1 F1—Avoid signalizing through roads (T)
	17.1 F2—Provide all-way stop control at appropriate intersections (P)
	17.1 F3—Provide roundabouts at appropriate locations (P)
17.1 G—Improve driver compliance with traffic control devices and traffic laws at intersections	17.1 G1—Provide targeted enforcement to reduce stop sign violations (T)
	17.1 G2—Provide targeted public information and education on safety problems at specific intersections (T)
17.1 H—Reduce operating speeds on specific intersection approaches	17.1 H1—Provide targeted speed enforcement (P)
	17.1 H2—Provide traffic calming on intersection approaches through a combination of geometrics and traffic control devices (P)
	17.1 H3—Post appropriate speed limit on intersection approaches (T)
17.1 I—Guide motorists more effectively through complex intersections	17.1 I1—Provide turn path markings (T)
	17.1 I2—Provide a double yellow centerline on the median opening of a divided highway at intersections (T)
	17.1 I3—Provide lane assignment signing or marking at complex intersections (T)

*See following section for explanation of “E,” “P,” and “T” designations.

Explanation of Strategy Types

The strategies in this guide were identified from a number of sources, including the literature, contact with state and local agencies throughout the United States, and federal programs. Some of the strategies are widely used, while others are used at a state or even a local level. Some have been subjected to well-designed evaluations to prove their effectiveness. However, it was found that many strategies, including some that are widely used, have not been adequately evaluated.

The implication of the widely varying experience with these strategies, as well as the range of knowledge about their effectiveness, is that the reader should be prepared to exercise caution in many cases before adopting a particular strategy for implementation. To help the reader, the strategies in the AASHTO guides have been classified into three types, each identified by a letter:

- Proven (P): Those strategies that have been used in one or more locations and for which properly designed evaluations have been conducted that show it to be effective. These strategies may be employed with a good degree of confidence, but with the understanding that any application can lead to results that vary significantly from those found in previous evaluations. The attributes of the strategies that are provided will help users judge which strategy is the most appropriate for the particular situation.
- Tried (T): Those strategies that have been implemented in a number of locations and may even be accepted as standards or standard approaches, but for which there have not been found valid evaluations. These strategies, while frequently or even generally used, should be applied with caution; users should carefully consider the attributes cited in the guide and relate them to the specific conditions for which they are being considered. There can be some degree of assurance that implementation will not likely have a negative impact on safety and will very likely have a positive one. It is the intent that as these strategies are continually implemented under the AASHTO Strategic Highway Safety Plan initiative, appropriate evaluations will be conducted so that effectiveness information can be accumulated to provide better estimating power for the user, and the strategy can be upgraded to a "proven" one.
- Experimental (E): Those strategies that have been suggested and that at least one agency has considered sufficiently promising to try on a small scale in at least one location. These strategies should be considered only after the others have been determined to be inappropriate or unfeasible. Even where they are considered, their implementation should initially occur using a very controlled and limited pilot study that includes a properly designed evaluation component. Only after careful testing and evaluation show the strategy to be effective should broader implementation be considered. It is intended that as the experiences of such pilot tests are accumulated from various state and local agencies, the aggregate experience can be used to further detail the attributes of this type of strategy, so that it can be upgraded to a "proven" one.

Related Strategies for Creating a Truly Comprehensive Approach

The strategies listed above and described in detail below are considered unique to this emphasis area. However, to create a truly comprehensive approach to the highway safety problems associated with this emphasis area, it is recommended that additional strategies be included as candidates in any program planning process. These additional strategies are of five types:

- Public Information and Education Programs (PI&E)—Many highway safety programs can be effectively enhanced with a properly designed PI&E campaign. The primary experience with PI&E campaigns in highway safety is to reach an audience across an entire jurisdiction or a significant part of it. However, it may be desired to focus a PI&E campaign on a location-specific problem. While this is a relatively untried approach compared with areawide campaigns, use of roadside signs and other experimental methods may be tried on a pilot basis.

Within this guide, PI&E campaigns, where application is deemed appropriate, are usually used in support of some other strategy. In such a case, the description for that strategy will suggest this possibility (in the exhibits, see the attribute area for each strategy entitled "Associated Needs"). In some cases, where PI&E campaigns are deemed unique for the emphasis area, the strategy is explained in detail. As additional guides are completed for the AASHTO plan, they may address the details regarding PI&E strategy design and implementation.

- <u>Enforcement of Traffic Laws</u>**—**Well-designed, well-operated law enforcement programs can have a significant effect on highway safety. It is well established, for instance, that an effective way to reduce crashes and their severity is to have jurisdictionwide programs that enforce an effective law against driving under the influence (DUI) or driving without seat belts. When that law is vigorously enforced with well-trained officers, the frequency and severity of highway crashes can be significantly reduced. This should be an important element in any comprehensive highway safety program.

  Enforcement programs, by the nature of how they must be performed, are conducted at specific locations. The effect (e.g., lower speeds, greater use of seat belts, and reduced impaired driving) may occur at or near the specific location where the enforcement is applied. This effect can often be enhanced by coordinating the effort with an appropriate PI&E program. However, in many cases (e.g., speeding and using seat belts), the impact is areawide or jurisdictionwide. The effect can be either positive (i.e., the desired reductions occur over a greater part of the system) or negative (i.e., the problem moves to another location as road users move to new routes where enforcement is not applied). Where it is not clear how the enforcement effort may impact behavior or where it is desired to try an innovative and untried method, a pilot program is recommended.

  Within this guide, where the application of enforcement programs is deemed appropriate, it is often in support of some other strategy. Many of those strategies may be targeted at either a whole system or a specific location. In such cases, the description for that strategy will suggest this possibility (in the exhibits, see the attribute area for each strategy entitled "Associated Needs"). In some cases, where an enforcement program is deemed unique for the emphasis area, the strategy will be explained in detail. As additional guides are completed for the AASHTO plan, they may address the details regarding the design and implementation of enforcement strategies.

- <u>Strategies to Improve Emergency Medical and Trauma System Services</u>**—**Treatment of injured parties at highway crashes can have a significant impact on the level of severity and length of time in which an individual spends treatment. This is especially true when it comes to timely and appropriate treatment of severely injured persons. Thus, a basic part of a highway safety infrastructure is a well-based and comprehensive emergency care program. While the types of strategies that are included here are often thought of as simply support services, they can be critical to the success of a comprehensive highway safety program. Therefore, for this emphasis area, an effort should be made to determine if there are improvements that can be made to this aspect of the system, especially for programs that focus upon location-specific (e.g., corridors) or area-specific (e.g., rural areas) issues. As additional guides are completed for the AASHTO plan, they may address the details regarding the design and implementation of emergency medical systems strategies.

- Strategies Directed at Improving the Safety Management System—There should be in place a sound organizational structure, as well as infrastructure of laws, policies, etc., to monitor, control, direct, and administer a comprehensive approach to highway safety. It is important that a comprehensive program not be limited to one jurisdiction, such as a state DOT. Local agencies often have jurisdiction over the majority of the road system and are responsible for its related safety problems. They know, better than others, what the problems are. As additional guides are completed for the AASHTO plan, the guides may address the details regarding the design and implementation of strategies for improving safety management systems.
- Strategies that Are Detailed in Other Emphasis Area Guides—Any program targeted at the safety problem covered in this emphasis area should be created with consideration given to these strategies, which are covered in other guides:
  - Curbing aggressive driving (Volume 1 of this report),
  - Keeping drivers with suspended and revoked licenses off the road (Volume 2 of this report),
  - Reducing run-off-road crashes (Volume 6 of this report),
  - Reducing utility-pole fatalities (guide under development),
  - Reducing pedestrian fatalities (guide under development),
  - Safely accommodating older drivers (guide under development), and
  - Reducing fatalities to unbelted drivers and occupants (guide under development).

Objective 17.1 A—Improve Management of Access Near Unsignalized Intersections

Strategy 17.1 A1—Implement Driveway Closures/Relocations (T)

General Description

Effective access management is key to improving safety at and adjacent to unsignalized intersections. Highway agencies are increasingly using access management techniques on urban and suburban arterials, following the lead established by the Colorado DOT, the Florida DOT, and others. The successful series of access management conferences sponsored by the Transportation Research Board have assisted in implementing this approach.

A key element of access management is closure or relocation of driveways adjacent to intersections. Access points within 250 feet upstream and downstream of an intersection are generally undesirable. Strategies for mitigating safety problems that may arise from a driveway located too close to an unsignalized intersection are to close the driveway (if other access to the adjacent property already exists) or to relocate the driveway (if no other appropriate access is available). It is desirable to relocate access points on the major-road approach to an intersection, to the minor-road approach (away from the intersection), or (where practical) to another street or frontage road. Where there is access from the minor road, from a side street, or from a frontage road, relocating the driveway on the major road farther from the intersection may be considered.

EXHIBIT V-2
Strategy Attributes for Implementing Driveway Closures/Relocations (T)

Technical Attributes	
Target	Unsignalized intersections with high crash frequencies related to driveways adjacent to the intersection. Generally, driveways within 250 feet of the intersection are the greatest concern.
Expected Effectiveness	The strategy of closing or relocating driveways adjacent to intersections is considered effective and has been addressed in published literature, but there is no consensus on quantitative estimates of its effectiveness. The safety effectiveness of this strategy is highly site dependent and will vary with the driveway location relative to the intersection before and after the project, the traffic volume using the driveway, the traffic volume and speed on the relevant intersection approaches, and the type of development served by the driveway. Further research and testing are needed to quantify the safety effectiveness of this strategy.
Keys to Success	The key to success is convincing adjacent property owners that some restriction of access to their property will improve safety and will not affect their ability (or, in the case of a retail business, their customers' ability) to reach their property. Where practical, these strategies should be implemented as part of a comprehensive corridor access management plan.
Potential Difficulties	Access restrictions could cause some owners of retail business 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 may be advisable to involve stakeholders at the early stages of planning for these improvements. For a comprehensive approach to this issue, see the Minnesota DOT guidelines for access management at http://www.oim.dot.state.mn.us/access/MnDOT_Access_Guidelines.pdf. For further information on access management and the FHWA Access Management Guide, see http://www.accessmanagement.gov/index.html. Another pitfall is that the provision for alternative access may result in a net degradation of or no improvement in overall safety due to increased travel required.
Appropriate Measures and Data	Process measures include the number of driveways closed or relocated within 250 feet of unsignalized intersections and the number of conflicts eliminated by turn restrictions. Crash frequency and severity, by type of crash, are key safety effectiveness measures. Where issues of potential effect on commercial operations exist, impact measures may be needed that reflect the change in sales or changes in other measures of economic activity. Crash frequency and severity data are needed to evaluate such improvements. If feasible, crashes related to access points on the intersection approach, as well as totals, should be analyzed separately. Traffic volume data are needed to represent exposure. In some cases, sales and other economic data may be needed to assess impacts on commercial operations whose access is affected.
Associated Needs	There is a definite need to inform the public, especially adjacent property owners, about the benefits of access management techniques and about methods to mitigate the adverse effects on access restrictions. There is also a need to develop, and document for future reference, the effects on business activity after the institution of access control techniques. This information could be used in negotiations with business and property owners.

EXHIBIT V-2 (Continued)
Strategy Attributes for Implementing Driveway Closures/Relocations (T)

Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	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-permitting staff within highway agencies also needs to have an understanding of the safety consequences of driveway requests. Nearly any highway agency can participate in implementing this strategy. While this strategy is applicable to both rural and urban locations, the greatest need is for agencies that operate extensive systems of urban and suburban arterials. Highway agencies should establish formal policies concerning driveways located near intersections to guide the planning and permitting process and to provide a basis for remedial treatments at existing locations where driveway-related safety problems occur.
Issues Affecting Implementation Time	Implementation of driveway closures and relocations can require 3 months to 3 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 Involved	Costs are highly variable; these costs mostly involve acquiring access or constructing replacement access.
Training and Other Personnel Needs	Training for highway agency personnel in access management techniques is important to help ensure that the strategies are properly implemented.
Legislative Needs	The power of a highway agency to modify access provisions is derived from legislation that varies in its provision from state to state. Highway agencies generally do not have the power to deny access to any particular parcel of land, but many do have the power to require, with adequate justification, relocation of access points. Where highway agency powers are not adequate to deal with driveways close to intersections, further legislation may be needed.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with the other strategies for improving safety at unsignalized intersections.
Key Attributes to a Particular Strategy	Since the safety effectiveness of this strategy has not been quantified, it would be desirable to conduct formal evaluations of any projects that are implemented.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

FHWA-RD-76-87, *Technical Guidelines for Direct Access Control to Arterial Highways* (Glennon, Valenta, Thorson, and Azzeh, 1976).

Median Handbook (Florida Department of Transportation, 1997).

NCHRP Report 420: Impacts of Access Management Techniques (Gluck, Levinson, and Stover, 1999), Transportation Research Board of the National Academies.

Strategy 17.1 A2—Implement Driveway Turn Restrictions (T)

General Description

When a driveway on a high-volume street adjacent to an unsignalized intersection cannot be closed or relocated, it may be appropriate to restrict turning maneuvers at the driveway. For example, left turns at the driveway can be restricted and driveway movements limited to right turns in and right turns out. In other cases, turning movements into a property may be permitted at a particular driveway, but turning movements out of the property may be diverted to a different driveway. Furthermore, driveway usage may be restricted at particularly critical times of the day. Such restrictions can be implemented by signing, by channelizing islands where the driveway enters the major street, by redesign of internal circulation patterns within a property, by provision of a median on the major street, or by a combination of these approaches.

EXHIBIT V-3
Strategy Attributes for Implementing Driveway Turn Restrictions (T)

Technical Attributes	
Target	The target for this strategy should be driveways located near unsignalized intersections that experience high crash frequencies but that cannot practically be closed or relocated.
Expected Effectiveness	Restricting turning maneuvers at driveways is considered effective, but there is no consensus on quantitative estimates of its effectiveness. The safety effectiveness of this strategy is highly site dependent and will vary with the traffic volume using the driveway, the traffic volume and speed on the relevant intersection approaches, and the type of development served by the driveway. Further research and testing are needed to quantify the safety effectiveness of this strategy.
Keys to Success	The key to success is convincing adjacent property owners that some restriction of access to their property will improve safety and will not affect their ability (or, in the case of a retail business, their customer's ability) to reach their property. Where practical, these strategies should be implemented as part of a comprehensive corridor access management plan. The development of the plans may be greatly facilitated by the inclusion of all the stakeholders early in the process.
Potential Difficulties	Access restrictions could cause some owners of retail business to lose customers (or at least think they will lose customers). This is highly dependent upon the type of business and the nature of the access restriction. Such impacts need to be carefully considered by highway agencies in implementing projects.

EXHIBIT V-3 (Continued)
Strategy Attributes for Implementing Driveway Turn Restrictions (T)

	For a comprehensive approach to this issue, see the Minnesota DOT guidelines for access management at http://www.oim.dot.state.mn.us/access/MnDOT_Access_Guidelines.pdf. For further information on access management and the FHWA Access Management Guide, see http://www.accessmanagement.gov/index.html.
Appropriate Measures and Data	Key *process measures* include the *number of driveways near intersections where turn restrictions are implemented* and the *number of conflicts eliminated by turn restrictions.* *Crash frequency and severity* are key safety effectiveness measures. Where commercial operations may be affected, impact measures may be needed reflecting the change in sales or changes in other measures of economic activity. Crash frequency and severity data by type of crash are needed to evaluate such improvements. If feasible, the crashes related to targeted turning movements at the driveway should be separately analyzed, as well as totals. Traffic volume data are needed to represent exposure. In addition, it will be useful when planning the improvements to estimate traffic conflicts resulting from the targeted turning movements. In some cases, sales and other economic data may be needed to assess impacts on commercial operations whose access is affected.
Associated Needs	There is a definite need to inform the public, especially adjacent property owners, about the safety benefits of access management techniques and about methods to mitigate the adverse effects of access restrictions. There is also a need to develop, and document for future reference, the effects on business activity after institution of access control techniques. This information could be used in negotiations with business and property owners.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	The optimal situation is to avoid driveway-related turning 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-permitting staff within highway agencies also needs to have an understanding of the safety consequences of driveway requests. Nearly any highway agency can participate in implementing these strategies. While this strategy is applicable to both rural and urban locations, the greatest need is at agencies that operate extensive systems of urban and suburban arterials. Highway agencies should establish formal policies concerning driveways located near intersections to guide the planning and permitting process and to provide a basis for remedial treatments at existing locations where driveway-related safety problems occur.
Issues Affecting Implementation Time	The time to implement this strategy can range from 3 months to 4 years. Turn restrictions implemented by signing alone can be implemented very quickly where the adjacent property owner is agreeable. Where changes in driveway channelization or internal circulation patterns are involved or where the property owner does not agree with the proposed change, additional time may be required. Where a median is to be installed on the major street, particularly if right-of-way acquisition is required, up to 4 years may be required for the project development process and construction of the improvement.
Costs Involved	Costs may be highly variable. Note that compensation is generally not owed to property owners for loss of direct left-turn access.

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EXHIBIT V-3 (Continued)
Strategy Attributes for Implementing Driveway Turn Restrictions (T)

Training and Other Personnel Needs	Training for highway agency personnel in access management techniques is important to help ensure that the strategies are properly implemented.
Legislative Needs	The power of a highway agency to modify access provisions is derived from legislation that varies in its provision from state to state. Highway agencies generally do not have the power to deny access to any particular parcel of land, but many have the power to require, with adequate justification, relocation of access points. Where highway agency powers to deal with driveways close to intersections are not adequate, further legislation may be needed.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with the other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	Since the safety effectiveness of this strategy has not been quantified, it would be desirable to conduct formal evaluations of any projects that are implemented. In particular, it would be desirable to document the effects on businesses of median closures or other turn restrictions for use in subsequent negotiations.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

FHWA-RD-76-87, *Technical Guidelines for Direct Access Control to Arterial Highways* (Glennon, Valenta, Thorson, and Azzeh, 1976).

Median Handbook (Florida Department of Transportation, 1997).

NCHRP Report 279: Intersection Channelization Design Guide (Neuman, 1985), Transportation Research Board of the National Academies.

NCHRP Report 420: Impacts of Access Management Techniques (Gluck, Levinson, and Stover, 1999), Transportation Research Board of the National Academies.

Objective 17.1 B—Reduce the Frequency and Severity of Intersection Conflicts through Geometric Design Improvements

Strategy 17.1 B1—Provide Left-Turn Lanes at Intersections (P)

General Description

Many collisions at unsignalized intersections are related to left-turn maneuvers. A key strategy for minimizing such collisions is to provide exclusive left-turn lanes, particularly on high-volume and high-speed major-road approaches (Exhibit V-4). Left-turn lanes remove vehicles waiting to turn left from the through-traffic stream, 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. This may reduce the potential for collisions between left-turn and opposing through vehicles.

EXHIBIT V-4
Exclusive Left-Turn Lane

EXHIBIT V-5
Strategy Attributes for Providing Left-Turn Lanes at Intersections (P)

Technical Attributes	
Target	The strategy is targeted to reduce the frequency of collisions resulting from the conflict between (1) vehicles turning left and following vehicles and (2) vehicles turning left and opposing through vehicles.
Expected Effectiveness	A group of experts, convened for a recent FHWA study, concluded from a review of literature that installation of left-turn lanes on the major road at unsignalized intersections reduces total crashes by 22 percent at three-legged intersections and 24 percent at four-legged intersections for a left-turn lane on one major-road approach, and by 42 percent for left-turn lanes on both major-road approaches (Harwood et al., 2000). These estimates of the effect of left-turn lanes on total intersection crashes were based on a thorough review of published literature. After the group of experts had met, additional research to assess the safety effectiveness of left-turn lanes at unsignalized intersections has been conducted for FHWA by Midwest Research Institute (MRI) (Harwood et al., 2002). MRI performed an extensive before-after evaluation of added turn lanes at intersections and found that added left-turn lanes are effective in improving safety at unsignalized intersections in both rural and urban areas. Installation of a single left-turn lane on a major-road approach would be expected to reduce total intersection accidents at rural unsignalized intersections by 28 percent for four-legged intersections and by 44 percent for three-legged intersections. At urban unsignalized intersections, installation of a left-turn lane on one approach would be expected to reduce total accidents by 27 percent for four-legged intersections and by 33 percent for three-legged intersections. Installation of left-turn lanes on both major-road approaches to a four-legged intersection would be expected to increase, but not quite double, the resulting effectiveness measures for total intersection accidents.

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EXHIBIT V-5 (Continued)
Strategy Attributes for Providing Left-Turn Lanes at Intersections (P)

Key to Success	The key to success in installing left-turn lanes is to make sure that any left-turn lane considered is operationally warranted (see Harmelink, 1967, for an example) or justified on the basis of an existing pattern of left-turn collisions. Otherwise, installation of a left-turn lane is unlikely to provide substantial safety benefits.
Potential Difficulties	In providing left-turn lanes, vehicles in opposing left-turn lanes may block their respective driver's view of approaching vehicles in the through lanes. This potential problem can be resolved by offsetting the left-turn lanes (see discussion of this under Strategy 17.1 B3). Other potential pitfalls may occur in implementing this strategy. For example, a decision may be made to restripe a shoulder and through lane to make provision for a left-turn lane. However, part of the safety benefits may be lost due to the loss of shoulder, the greater proximity of traffic to roadside objects, and, possibly, a reduction in intersection sight distance (ISD). Provision of a left-turn lane on an intersection approach may involve restricting left turns in and out of driveways on that intersection approach. Such restrictions may be implemented by signing or by provision of a median adjacent to the left-turn lane. Approaches to dealing with such issues are discussed in connection with Strategy 17.1 A1. When installation of left-turn lanes increases the overall width of the intersection, the additional width may cause problems for pedestrians crossing the intersection. One possible solution to this problem is to provide a pedestrian refuge island in the median.
Appropriate Measures and Data	Key process measures include the *number of intersection approaches for which left-turn lanes are implemented* and the *number of conflicts eliminated by the improvement.* *Crash frequency and severity, by type of crash,* are key safety effectiveness measures. It is especially useful to identify crashes related to left turns and analyze them separately. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crashes and crashes related to the targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure. It is especially desirable to obtain data on the volume of vehicles making the left-turn movements of interest and the opposing through volumes.
Associated Needs	There is a definite need to inform the public, especially adjacent property owners, about the safety benefits of access management techniques and about methods to mitigate the adverse effects on any access restrictions associated with the provision of left-turn lanes.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway and other agencies should ensure that their design policies for new or reconstructed intersections incorporate provision of left-turn lanes. Highway agencies should review their traffic engineering and design policies regarding use of left-turn lanes to ensure that appropriate action is being taken on routine projects. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.

EXHIBIT V-5 (Continued)
Strategy Attributes for Providing Left-Turn Lanes at Intersections (P)

Issues Affecting Implementation Time	Implementation time may vary from 3 months to 4 years. At some locations, left-turn lanes can be quickly installed simply by restriping the roadway. At other locations, widening the roadway, installing a median, or acquiring additional right-of-way may be needed. Such projects require a substantial time for development and construction. Where right-of-way is required or where the environmental process requires analysis and documentation, project development and implementation may require as long as 4 years.
Costs Involved	Costs are highly variable. Where restriping within an existing roadway is possible, the costs are nominal. Where widening and/or reconstruction are necessary, costs over $100,000 per intersection approach may be incurred. Potential funding sources include federal, state, and local highway agencies.
Training and Other Personnel Needs	Effective use of left-turn lanes should be addressed in highway agency training concerning access management and intersection operation.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	Optimal operation and safety of left-turn lanes requires their appropriate design. This includes sufficient length of lane and taper (see Strategy 17.1 B2).

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

FHWA-RD-02-089, *Safety Effectiveness of Intersection Left- and Right-Turn Lanes* (Harwood, Bauer, Potts, Torbic, Richard, Kohlman Rabbani, Hauer, and Elefteriadou, 2002).

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

NCHRP Report 279: Intersection Channelization Design Guide (Neuman, 1985), Transportation Research Board of the National Academies.

Highway Research Record 211, “Volume Warrants for Left-Turn Storage Lanes at Unsignalized Grade Intersections” (Harmelink, 1967), Highway Research Board of the National Academies.

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

Strategy 17.1 B2—Provide Longer Left-Turn Lanes at Intersections (T)

General Description

The length of a left-turn lane is among its most important design elements. Left-turn lanes should be designed to accommodate vehicle deceleration and storage. In particular, the left-turn lane length should allow for the removal of slow or decelerating vehicles from through-traffic, thus reducing the potential for rear-end collisions. The length of a left-turn lane consists of three components: (1) entering taper, (2) deceleration length, and (3) storage length. Design criteria for selecting an appropriate left-turn lane length are presented in the AASHTO *Policy on Geometric Design for Highways and Streets* and in the policies of individual highway agencies (AASHTO, 2001).

EXHIBIT V-6
Strategy Attributes for Providing Longer Left-Turn Lanes at Intersections (T)

Technical Attributes	
Target	The strategy is targeted to reduce the frequency of rear-end collisions resulting from the conflict between vehicles waiting to turn left and following vehicles. The strategy is appropriate for application at intersection approaches that have existing left-turn lanes that are not long enough to store all left-turning vehicles.
Expected Effectiveness	This strategy will reduce rear-end collisions resulting from conflicts between vehicles waiting to turn left and following vehicles during periods when the left-turn demand exceeds the existing storage capacity of the left-turn lane. When a queue of vehicles overflows the left-turn lane and extends into the through lanes of the intersection approach, rear-end collisions are likely. Such overflows may also result in operational delays to through or right-turning vehicles. Lengthening of left-turn lanes may also reduce the potential for rear-end collisions between left-turning vehicles by providing longer entering taper and deceleration lengths. There is no consensus on a quantitative estimate of the safety effectiveness of lengthening left-turn lanes. This effectiveness is likely to depend on the existing length of the left-turn lane, the proportion of time during which the storage capacity of the left-turn lane is exceeded, the volume and speed of traffic on the intersection approach, and the available sight distance to the rear of the left-turn queue. Further research to quantify the safety effectiveness of lengthening left-turn lanes is needed.
Key to Success	The key to success in lengthening left-turn lanes is to make sure that a longer left-turn lane is warranted or justified on the basis of left-turn volumes or an existing pattern of left-turn collisions.
Potential Difficulties	If a left-turn lane is excessively long, drivers proceeding through the intersection may enter the lane by mistake without realizing that it is a left-turn lane. This difficulty may be remedied by effective signing, marking, and/or median geometrics at the upstream end of the left-turn lane. Also, if a decision is made to provide a longer left-turn lane by restriping a shoulder and through lane, part of the safety benefits from the improvement may be lost because of the loss of shoulder and the greater proximity of through or right-turning traffic to roadside objects and possibly because of a reduction in intersection sight distance, as well.

EXHIBIT V-6 (Continued)
Strategy Attributes for Providing Longer Left-Turn Lanes at Intersections (T)

	Lengthening of a left-turn lane on an intersection approach may involve restricting left turns in and out of driveways on that intersection approach. Such restrictions may be implemented by signing or by provision of a median adjacent to the left-turn lane. Approaches to dealing with such issues are discussed in connection with Strategy 17.1 B1.
Appropriate Measures and Data	Key *process measures* include the *number of intersection approaches on which turn lanes are lengthened* and the *number of conflicts eliminated by the improvement.* *Crash frequency and severity, by type,* are key safety effectiveness measures. It is especially useful to identify crashes related to left turns (particularly rear-end collisions) and analyze them separately. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crashes and rear-end crashes related to targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure. It is especially desirable to obtain data on the volume of vehicles making the left-turn movement of interest, the through volumes on the same approach, and the reduction in duration of any periods during which left-turn traffic overflows into the adjacent through lane.
Associated Needs	There is a definite need to inform the public, especially adjacent property owners, about the safety benefits of access management techniques and about methods to mitigate the adverse effects on any access restrictions associated with the lengthening of left-turn lanes.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Highway agencies should ensure that their design policies for new or reconstructed intersections incorporate provision of lengthening left-turn lanes. Highway agencies should review their traffic engineering and design policies regarding length of left-turn lanes to ensure that appropriate action is being taken on routine projects. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas. Where alternatives may involve restricting access, it will be important to involve those potentially affected from the early stages of the planning.
Issues Affecting Implementation Time	Implementation time may vary from 3 months to 4 years. At some locations, left-turn lanes can be lengthened simply by restriping the roadway. Others may require widening the roadway, cutting further into a median, or acquiring additional right-of-way. Such projects require a substantial time for development and construction. Where right-of-way is required or where the environmental process requires analysis and documentation, the time will be longer.
Costs Involved	Costs are highly variable. Where restriping within an existing roadway is possible, the costs are nominal. Where widening and/or reconstruction are necessary, costs over $100,000 per intersection approach may be incurred.
Training and Other Personnel Needs	Effective use of left-turn lanes, including selection of an appropriate left-turn lane length, should be addressed in highway agency training concerning access management and intersection operation.
Legislative Needs	None identified.

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EXHIBIT V-6 (Continued)
Strategy Attributes for Providing Longer Left-Turn Lanes at Intersections (T)

Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	Optimal operation and safety of left-turn lanes require appropriate design. This includes sufficient length of lane and taper.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

Highway Research Record 211, "Volume Warrants for Left-Turn Storage Lanes at Unsignalized Grade Intersections" (Harmelink, 1967), Highway Research Board of the National Academies.

NCHRP Report 279: Intersection Channelization Design Guide (Neuman, 1985), Transportation Research Board of the National Academies.

NCHRP Synthesis of Highway Practice 225: Left-Turn Treatments at Intersections (Pline, 1996), Transportation Research Board of the National Academies.

Strategy 17.1 B3—Provide Offset Left-Turn Lanes at Intersections (T)

General Description

A potential problem in installing left-turn lanes at intersections is that vehicles in opposing turn lanes on the major road may block drivers' views of approaching traffic. This can lead to collisions between vehicles turning left from the major road and through vehicles on the opposing major-road approach. To reduce the potential for crashes of this type, the left-turn lanes can be offset by moving them laterally so that vehicles in opposing lanes no longer obstruct the opposing driver. Two treatments for offsetting turn lanes are parallel and tapered offset left-turn lanes. These treatments have been evaluated in research (Harwood et al., 1995) and are addressed in the AASHTO *Policy on Geometric Design of Highways and Streets* (AASHTO, 2001). While offset left-turn lanes have been used most extensively at signalized intersections, they are suitable for use at unsignalized intersections as well.

EXHIBIT V-7
Strategy Attributes for Providing Offset Left-Turn Lanes at Intersections (T)

Technical Attributes	
Target	The strategy of providing offset left-turn lanes at unsignalized intersections is targeted to reduce the frequency of collisions between vehicles turning left and opposing through vehicles, as well as rear-end crashes between through vehicles on the opposing approach. The strategy is generally applicable to intersections on divided highways with medians wide enough to provide the appropriate offset.

EXHIBIT V-7 (Continued)
Strategy Attributes for Providing Offset Left-Turn Lanes at Intersections (T)

Expected Effectiveness	Research has verified that offset left-turn lanes operate safely (Harwood et al., 1995), but there are no reliable estimates of their safety effectiveness. Safety effectiveness is likely to depend upon the traffic volumes of the conflicting turning and through movements and the amount of offset between the left-turn lanes at the intersection.
Key to Success	A key to success in installing offset left-turn lanes is to identify candidate locations at which opposing left-turn vehicles block drivers' views of approaching traffic. This can be determined by measuring the amount of offset (or lack of offset) present at existing intersections (McCoy et al., 1992). Any intersection with a pattern of collisions between left-turning vehicles and opposing through vehicles that has existing left-turn lanes (or at which installation of left-turn lanes is being considered) should be checked to determine the amount of available offset.
Potential Difficulties	A potential pitfall of installing offset left-turn lanes is that drivers initially may be confused by the change in traffic patterns, particularly in areas where offset left-turn lanes have not been used previously. This can be minimized by effective use of advance guide signing and pavement markings. Research has verified that, in areas where drivers have become familiar with offset left-turn lanes, they operate effectively (Harwood et al., 1995). When installation of offset left-turn lanes increases the overall width of the intersection, the additional width may cause potential problems for pedestrians crossing the intersection. One possible solution to this problem is to provide a refuge island in the median for pedestrians.
Appropriate Measures and Data	Key *process measures* include the *number of intersection approaches for which left-turn lane offsets are implemented* and the *number of conflicts affected by the improvements.* *Crash frequency and severity* are key safety effectiveness measures. Separate analysis of the crash types targeted by the improvement (see above) is desirable. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crashes and crashes related to targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	Public information and education programs about the operation of offset left-turn lanes and their potential safety benefits should be considered when such treatments are used for the first time in a given area. Such programs can be useful in familiarizing drivers with the intended operation of offset left-turn lanes.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Highway agencies should consider the adoption of offset left-turn lanes as standard practice for typical intersection designs for highways with wide medians. Nearly any highway agency can make use of this strategy. While the strategy is potentially applicable to rural, urban, and suburban areas, its primary application is on urban and suburban arterials. Policy guidance on the use of offset left-turn lanes is presented in the AASHTO *Policy on Geometric Design of Highways and Streets.* Highway agencies that use this design should consider incorporating it in their own design manuals and guides.

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EXHIBIT V-7 (Continued)
Strategy Attributes for Providing Offset Left-Turn Lanes at Intersections (T)

Issues Affecting Implementation Time	The implementation period for provision of offset left-turn lanes is 2 to 4 years. Intersections at which offset left-turn lanes can be provided simply by restriping the roadway are relatively rare. Therefore, time for project development and construction is required. Where a wide median is available, offset left-turn lanes can usually be provided without purchasing additional right-of-way; in such cases, implementation in 2 years may be possible. If the median must be widened, additional right-of-way may be needed and there may be substantial social and environmental impacts that need to be evaluated; in such cases, the implementation may take up to 4 years. The implementation period can be reduced where an agency adopts this design by policy and implements it on projects in preliminary or final design.
Costs Involved	Costs may be highly variable and depend largely on the existing median width.
Training and Other Personnel Needs	Effective use of offset left-turn lanes should be addressed in highway agency training concerning access management and intersection operation.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

Transportation Research Record 1356, "Guidelines for Offsetting Opposing Left-Turn Lanes on Four-Lane Divided Roadways" (McCoy, Navarro, and Witt, 1992), Transportation Research Board of the National Academies.

Transportation Research Record 1356, "Mitigation of Sight-Distance Problem for Unprotected Left-Turning Traffic at Intersections" (Joshua and Saka, 1992), Transportation Research Board of the National Academies.

Strategy 17.1 B4—Provide Bypass Lanes on Shoulders at T-Intersections (T)

General Description

At three-legged intersections on two-lane highways, shoulder bypass lanes can provide an effective substitute for a left-turn lane on the major road where provision of a left-turn lane is economically infeasible. Instead of providing a left-turn lane for drivers turning left from the major road, part of the shoulder may be marked as a travel lane to encourage following through drivers to use this shoulder lane to bypass vehicles waiting to turn left. This treatment involves substantially less cost than providing a conventional left-turn lane and, at low-volume intersections, it may be just as effective.

EXHIBIT V-8
Strategy Attributes for Providing Bypass Lanes on Shoulders at T-Intersections (T)

Technical Attributes	
Target	The target for this strategy should be three-legged unsignalized intersections on two-lane highways with moderate through and turning volumes, especially intersections that have a pattern of rear-end collisions involving vehicles waiting to turn left from the highway.
Expected Effectiveness	Minnesota evaluated the operational and safety effects of using bypass lanes at rural intersections by comparing the operational and safety characteristics of rural intersections without turning lanes, with bypass lanes, and with left-turn lanes (Preston and Schoenecker, 1999a). Based upon a comparative crash analysis and a before-after evaluation, Minnesota was unable to conclude that the use of a bypass lane provides a greater degree of safety when compared with intersections without a bypass lane or a left-turn lane. However, Nebraska has reported a marked decrease in rear-end collisions at shoulder bypass lanes, and other states have reported relatively few accidents occurring at shoulder bypass lane installations (Sebastian and Pusey, 1982). Additional evaluations are necessary to sufficiently quantify the safety effectiveness of bypass lanes on shoulders.
Key to Success	A key to success is providing a shoulder area for the bypass lane that has sufficient structural strength to withstand repeated usage, even by trucks.
Potential Difficulties	There may be an upper limit of traffic volumes above which shoulder bypass lanes should not be used. No such limit has been quantified, but highway agencies should still consider carefully the appropriateness of shoulder bypass lanes on high-volume two-lane roads. Shoulder bypass lanes should not be viewed as a substitute for conventional left-turn lanes as part of a reconstruction or major redesign project where right-of-way is available and construction feasible.
Appropriate Measures and Data	Key *process measures* include the *number of intersection approaches where bypass lanes are implemented* and the *number of potential rear-end conflicts eliminated by the improvements.* *Crash frequency and severity, by type,* are key safety effectiveness measures. Separate analysis of rear-end crashes targeted by the improvement is desirable. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crashes and crashes related to targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure.

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EXHIBIT V-8 (Continued)
Strategy Attributes for Providing Bypass Lanes on Shoulders at T-Intersections (T)

Associated Needs	Most drivers understand shoulder bypass lanes readily. There are no particular public information and education needs to be addressed when they are used.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should consider the adoption of bypass lanes as standard practice for new or reconstructed three-legged unsignalized intersections where left-turn lanes are not feasible. Nearly any highway agency that operates a two-lane highway system can participate in implementing this strategy. While this strategy is potentially applicable to both rural and urban locations, shoulder bypass lanes are most appropriate for application in rural areas. Highway agencies that use shoulder bypass lanes should incorporate this treatment in their design manuals or guides.
Issues Affecting Implementation Time	This strategy can be implemented within 3 months at locations with an existing paved shoulder. Some locations may need only pavement marking and signing changes. Paving an unpaved shoulder or strengthening a paved shoulder may take longer. In rare cases where acquisition of right-of-way is needed, a project development process of up to 4 years may be required.
Costs Involved	Costs should be relatively low since little to no additional right-of-way is necessary for this strategy. Construction involves paving and marking a portion of the existing shoulder.
Training and Other Personnel Needs	Appropriate uses of shoulder bypass lanes should be included in geometric design training, particularly in training courses about two-lane highways.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most others for improving safety at unsignalized intersections. It is, however, an alternative to providing a left-turn lane.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Delaware Department of Transportation, *Paved-Shoulders Left-Turn By-Pass Lanes: A Report on the Delaware Experience* (Sebastian and Pusey, 1982).

FHWA-IP-87-2, *Low-Cost Methods for Improving Traffic Operations on Two-Lane Roads* (Harwood and Hoban, 1987).

MN/RC–2000–22, Bypass Lane Safety, Operations, and Design Study (Preston and Schoenecker, 1999a).

Strategy 17.1 B5—Provide Left-Turn Acceleration Lanes at Divided Highway Intersections (T)

General Description

Drivers turning onto a highway accelerate until the desired highway speed is reached. When acceleration by entering traffic takes place directly on the traveled way, it may disrupt the flow of through-traffic. To minimize this operational problem due to left-turning traffic at divided highway intersections, median acceleration lanes may be used. An acceleration lane is an auxiliary or speed-change lane that allows vehicles to accelerate to highway speeds before entering the through-traffic lanes of a highway. Acceleration lanes should be of sufficient length to permit adjustments in speeds of both through and entering vehicles so that the driver of the entering vehicle can position the vehicle opposite a gap in the through-traffic stream and maneuver into that gap before reaching the end of the acceleration lane.

EXHIBIT V-9
Strategy Attributes for Providing Left-Turn Acceleration Lanes at Divided Highway Intersections (T)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections on divided highways that experience a high proportion of rear-end collisions related to the speed differential caused by vehicles turning left onto the highway. Acceleration lanes should also be considered where intersection sight distance is inadequate or where there are high volumes of trucks entering the divided highway.
Expected Effectiveness	By removing the slower left-turning vehicles from the through lanes, this strategy is expected to reduce rear-end and sideswipe collisions resulting from conflicts between vehicles turning left onto the highway and through vehicles on the highway. Research has shown that left-turn acceleration lanes at divided highway intersections function effectively and do not create safety problems (Harwood et al., 1995). However, no quantitative estimates of the safety effectiveness of left-turn acceleration lanes at divided highway intersections are available. Further research is needed to provide quantitative estimates of the safety effectiveness of left-turn acceleration lanes at divided highway intersections.
Key to Success	A key to success in providing left-turn acceleration lanes is to make sure that they are operationally warranted by relatively high left-turn volumes or justified on the basis of an existing pattern of rear-end or sideswipe collisions related to left-turn maneuvers.
Potential Difficulties	If a left-turn acceleration lane is excessively long or poorly marked, through drivers may mistake it for an additional through lane. A key to operational success of median left-turn lanes is appropriate design of the median opening area to minimize conflicts between vehicles entering the left-turn acceleration lane and other through and turning vehicles using the median opening. There is little guidance available on the best geometric design for median acceleration lanes. Both parallel and tapered acceleration-lane design have been used. The AASHTO *Policy on Geometric Design for Highways and Streets* provides guidance on the design of acceleration lanes for freeway entrance ramps, but there is no specific design guidance for acceleration lanes at divided highway intersections.

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EXHIBIT V-9 (Continued)
Strategy Attributes for Providing Left-Turn Acceleration Lanes at Divided Highway Intersections (T)

	When installation of left-turn acceleration lanes increases the overall width of the intersection, the additional width may cause potential problems for pedestrians crossing the intersection. One possible solution to this problem is to provide a pedestrian refuge island in the median.
Appropriate Measures and Data	Key process measures include *the number of intersection departure roadways on which acceleration lanes are provided* and *the number of conflicts eliminated by the improvement.* *Crash frequency and severity, by type,* are key safety effectiveness measures. It is especially useful to identify crashes related to left turns onto the divided highway and analyze them separately. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crashes and rear-end and sideswipe crashes related to the targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure. Additional key traffic volume data include left-turn volumes, through volumes, and vehicle mix.
Associated Needs	Most drivers understand left-turn acceleration lanes and use them correctly. Where left-turn acceleration lanes are first introduced in an area, a public information and education campaign to explain their proper use may be desirable. The focus of such a campaign should generally be properly entering the acceleration lane from the median opening area.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that their design policies for new or reconstructed intersections incorporate provision of left-turn acceleration lanes on divided highways. Highway agencies should review their traffic engineering and design policies regarding left-turn acceleration lanes to ensure that appropriate action is being taken on routine projects. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.
Issues Affecting Implementation Time	Implementation time of left-turn acceleration lanes at divided highway intersections may vary from 3 months to 4 years. At some locations, left-turn acceleration lanes can be constructed simply by restriping the roadway. At other locations, widening the roadway, cutting further into a median, or acquiring additional right-of-way may be needed. Such projects may require a substantial time for development and construction. Where additional right-of-way is required or where the environmental process requires analysis and documentation, project implementation may take up to 4 years.
Costs Involved	Costs are highly variable. Where sufficient median width to provide a left-turn acceleration lane is available, it may be possible to provide a median acceleration lane at moderate cost. Where additional right-of-way must be acquired, higher costs are likely.
Training and Other Personnel Needs	Left-turn acceleration lanes at divided highway intersections should be included in highway agency training concerning geometric design.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.

EXHIBIT V-9 (Continued)
Strategy Attributes for Providing Left-Turn Acceleration Lanes at Divided Highway Intersections (T)

Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

Institute of Transportation Engineers, "Effectiveness of Median Storage and Acceleration Lanes for Left-Turning Vehicles," *ITE Journal,* Vol. 55, No. 3 (1985).

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

Strategy 17.1 B6—Provide Right-Turn Lanes at Intersections (P)

General Description

Many collisions at unsignalized intersections are related to right-turn maneuvers. A key strategy for minimizing such collisions is to provide exclusive right-turn lanes, particularly on high-volume and high-speed major-road approaches (Exhibit V-10). Right-turn lanes remove slow vehicles that are decelerating to turn right from the through-traffic stream, thus reducing the potential for rear-end collisions.

EXHIBIT V-10
Exclusive Right-Turn Lane

EXHIBIT V-11
Strategy Attributes for Providing Right-Turn Lanes at Intersections (P)

Technical Attributes	
Target	The strategy is targeted to reduce the 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.
Expected Effectiveness	A group of experts, convened for a recent FHWA study, concluded from a review of literature that installation of right-turn lanes on the major road at unsignalized intersections reduces total crashes by 5 percent at three-legged and four-legged intersections for a right-turn lane on one major-road approach, and by 10 percent for right-turn lanes on both major-road approaches (Harwood et al., 2000). These estimates of the effect of right-turn lanes on total intersection crashes were based on a thorough review of published literature. After the panel of experts met, additional research to assess the safety effectiveness of right-turn lanes at unsignalized intersections has been conducted for FHWA by Midwest Research Institute (MRI) (Harwood et al., 2002). MRI performed an extensive before-after evaluation of adding turn lanes at intersections and found that added right-turn lanes are effective in improving safety at rural unsignalized intersections. Installation of a single right-turn lane on a major-road approach would be expected to reduce total intersection accidents at rural unsignalized intersections by 14 percent. Installation of right-turn lanes on both major-road approaches to a four-legged intersection would be expected to increase, but not quite double, the resulting effectiveness measures for total intersection accidents. MRI also found that right-turn lane installation reduced accidents on individual approaches to four-legged intersections by 27 percent at rural unsignalized intersections.
Keys to Success	A key to success in installing right-turn lanes is to make sure that any right-turn lane considered is operationally justified on the basis of right-turning volumes or an existing pattern of right-turn collisions. Otherwise, installation of a right-turn lane is unlikely to provide substantial safety benefits. At some locations, it may be desirable to create a right-turn roadway by a channelizing island on the intersection approach. This allows the turning radius to be increased without introducing a large unused pavement area that might lead to operational problems. The right-turn roadway may be controlled by a yield sign where the roadway enters the intersecting street or may operate as a free-flow roadway where a right-turn acceleration lane is provided on the intersecting street (see Strategy 17.1 B8).
Potential Difficulties	One of the potential problems with installing a right-turn lane may occur in the design stage of this strategy. If, for example, a decision is made to restripe a shoulder and through lane to provide a right-turn lane, part of the safety benefits may be lost due to the loss of shoulder and the greater proximity of traffic to roadside objects. The effect of major-road right-turn lanes on the available sight distance for vehicles entering or crossing the major road from the adjacent minor-road approach should be considered in the design process. Vehicles using a major-road right-turn lane may obstruct the sight lines of drivers on the minor-road approach. Similarly, addition of the right-turn lane may be accompanied by shifting of the minor-road stop bar. Care should be taken to ensure that the sight triangle remains clear of obstructions on the stopped approach. When installation of right-turn lanes increases the overall width of the intersection, the additional width may cause potential problems for pedestrians crossing the intersection. One possible solution to this problem is to provide a pedestrian refuge island in the median.

EXHIBIT V-11 (Continued)
Strategy Attributes for Providing Right-Turn Lanes at Intersections (P)

Appropriate Measures and Data	Key *process measures* include *the number of intersection approaches where turn lanes are implemented* and *the number of conflicts eliminated by the improvement.* *Crash frequency and severity, by type,* are key safety effectiveness measures. It is especially useful to identify crashes related to right turns and analyze them separately. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crashes and crashes related to the targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	Most drivers understand the operation of right-turn lanes. There is no need for special public information and education programs.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that their design policies for new or reconstructed intersections incorporate provision for right-turn lanes. In areas used by pedestrians, policies for free-flow right-turn roadways in conjunction with right-turn lanes should be carefully considered. Federal accessibility regulations currently under development may require signalization of pedestrian crossings at free-flow right-turn roadways. Highway agencies should review their traffic engineering and design policies regarding use of right-turn lanes to ensure that appropriate action is being taken on routine projects. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.
Issues Affecting Implementation Time	Implementing this strategy may take from 3 months to 4 years. At some locations, right-turn lanes can be quickly and simply installed by restriping the roadway. At other locations, widening of the roadway or acquisition of additional right-of-way may be needed. Such projects require a substantial time for development and construction. Where right-of-way is required or where the environmental process requires analysis and documentation, project development and implementation may require as long as 4 years.
Costs Involved	Costs are highly variable. Where restriping within an existing roadway is possible, the costs are nominal. Where widening and/or reconstruction are necessary, costs over $100,000 per intersection approach may be incurred.
Training and Other Personnel Needs	Effective use of right-turn lanes should be included in highway agency training concerning geometric design.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	Optimal operation and safety of right-turn lanes requires their appropriate design. This includes sufficient length of lane and taper.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

FHWA-RD-02-089, *Safety Effectiveness of Intersection Left- and Right-Turn Lanes* (Harwood, Bauer, Potts, Torbic, Richard, Kohlman Rabbani, Hauer, and Elefteriadou, 2002).

NCHRP Report 279: Intersection Channelization Design Guide (Neuman, 1985), Transportation Research Board of the National Academies.

Strategy 17.1 B7—Provide Longer Right-Turn Lanes at Intersections (T)

General Description

The provision of exclusive right-turn lanes minimizes collisions related to right-turn maneuvers, particularly on high-volume and high-speed major roads. However, if the length of a right-turn lane is inadequate, vehicles waiting to turn may be doing so from the through-traffic lane, thus increasing the potential for rear-end collisions. If long enough, right-turn lanes provide sheltered locations for drivers decelerating or waiting to make a right-turn maneuver. The length of a right-turn lane consists of three components: (1) entering taper, (2) deceleration length, and (3) 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* and in the policies of individual highway agencies.

EXHIBIT V-12
Strategy Attributes for Providing Longer Right-Turn Lanes at Intersections (T)

Technical Attributes	
Target	The strategy is targeted to reduce the frequency of rear-end collisions resulting from the conflict between vehicles waiting to turn right and following vehicles. The strategy is appropriate for application on intersection approaches that have an existing right-turn lane that is not long enough to store all right-turning vehicles.
Expected Effectiveness	This strategy will reduce rear-end collisions resulting from the conflict between vehicles waiting to turn right and following vehicles during the period when right-turn demand exceeds the storage capacity of the right-turn lane. When a queue of vehicles overflows the right-turn lane and extends into the through lanes of the intersection approach, rear-end collisions are likely. Such overflows may also result in operational delays to through or left-turning vehicles. Lengthening of right-turn lanes may also reduce the potential for rear-end collisions between right-turning vehicles by providing longer entering taper and deceleration lengths. There is no consensus on a quantitative estimate of the safety effectiveness of lengthening right-turn lanes. This effectiveness is likely to depend on the existing length of the right-turn lane, the proportion of time during which the storage capacity of the right-turn lane is exceeded, the volume and speed of traffic on the intersection approach, and the available sight distance to the rear of the right-turn queue. Further research to quantify the safety effectiveness of lengthening right-turn lanes is needed.

EXHIBIT V-12 (Continued)
Strategy Attributes for Providing Longer Right-Turn Lanes at Intersections (T)

Key to Success	The key to success in lengthening right-turn lanes is to make sure that a longer right-turn lane is warranted or justified on the basis of right-turn volumes or an existing pattern of right-turn collisions. If access to adjacent properties will potentially be affected, it will be important to include the stakeholders early in the planning process.
Potential Difficulties	If a right-turn lane is excessively long, through drivers may enter the lane by mistake without realizing it is a right-turn lane. Effective signing and marking of the upstream end of the right-turn lane may remedy this difficulty. Also, a decision may be made to provide a longer right-turn lane by restriping a shoulder and through lane. In such cases, part of the safety benefits from the improvement may be lost due to the loss of shoulder, the greater proximity of through or right-turning traffic to roadside objects, and possibly a reduction in intersection sight distance, as well. Lengthening of a right-turn lane on an intersection approach may involve restricting right turns in and out of driveways on that intersection approach. Such restrictions may be implemented by signing or by provision of a median. Approaches to dealing with such issues are discussed in connection with Strategy 17.1 B6.
Appropriate Measures and Data	Key *process measures* include the *number of intersection approaches on which turn lanes are lengthened* and the *number of conflicts eliminated by the improvement.* *Crash frequency and severity, by type,* are key safety effectiveness measures. It is especially useful to identify crashes related to right turns (particularly rear-end collisions) and analyze them separately. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crashes and rear-end crashes related to targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure. It is especially desirable to obtain data on the volume of vehicles making the right-turn movements of interest, the through volumes on the same approach, and the reduction in duration of any periods during which right-turn traffic overflows into the adjacent through lane.
Associated Needs	There is a definite need to inform the public, especially adjacent property owners, about the safety benefits of access management techniques and about methods to mitigate the adverse effects on any access restrictions associated with the lengthening of right-turn lanes.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Highway agencies should ensure that their design policies for new or reconstructed intersections incorporate provision of lengthening right-turn lanes. Highway agencies should review their traffic engineering and design policies regarding length of right-turn lanes to ensure that appropriate action is being taken on routine projects. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.

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EXHIBIT V-12 (Continued)
Strategy Attributes for Providing Longer Right-Turn Lanes at Intersections (T)

Issues Affecting Implementation Time	Implementation may require from 3 months to 4 years. At some locations, right-turn lanes can be lengthened simply by restriping the roadway. Others may require widening the roadway, cutting further into a median, or acquiring additional right-of-way. Such projects require a substantial time for development and construction. Where right-of-way is required or where the environmental process requires analysis and documentation, the time will be longer.
Costs Involved	Costs are highly variable. Where restriping within an existing roadway is possible, the costs are nominal. Where widening and/or reconstruction are necessary, costs over $100,000 per intersection approach may be incurred.
Training and Other Personnel Needs	Effective use of longer right-turn lanes, including selection of an appropriate right-turn lane length, should be addressed in highway agency training concerning access management and intersection operation.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	Optimal operation and safety of right-turn lanes requires appropriate design. This includes sufficient length of lane and taper.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets* (2001).

NCHRP Report 279: Intersection Channelization Design Guide (Neuman, 1985), Transportation Research Board of the National Academies.

Strategy 17.1 B8—Provide Offset Right-Turn Lanes at Intersections (T)

General Description

A potential problem in installing right-turn lanes at intersections is that vehicles in the right-turn lane on the major road may block the minor-road drivers' views of traffic approaching on the major road. This can lead to collisions between vehicles turning left, turning right, or crossing from the minor road and through vehicles on the major road. To reduce the potential for crashes of this type, the right-turn lanes can be offset by moving them laterally so that vehicles in the right-turn lanes no longer obstruct the view of the minor-road driver (Exhibit V-13).

EXHIBIT V-13
Offset Right-Turn Lane

EXHIBIT V-14
Strategy Attributes for Providing Offset Right-Turn Lanes at Intersections (T)

Technical Attributes	
Target	The strategy of providing offset right-turn lanes at unsignalized intersections is targeted to reduce the frequency of collisions between vehicles turning left, turning right, or crossing from the minor road and through vehicles on the major road.
Expected Effectiveness	No research has been conducted on offset right-turn lanes to determine their safety effectiveness. Safety effectiveness is likely to depend upon the traffic volumes of the conflicting turning and through movements and the amount of offset between the right-turn lanes at the intersection.
Key to Success	A key to success in installing offset right-turn lanes is to identify candidate locations at which right-turn vehicles block drivers' views of approaching traffic. Any intersection with a pattern of collisions between minor-road vehicles and major-road vehicles with existing right-turn lanes (or at which installation of right-turn lanes is being considered) should be checked to determine the amount of available offset.
Potential Difficulties	A potential pitfall of installing offset right-turn lanes is that drivers initially may be confused by the change in traffic patterns, particularly in areas where offset right-turn lanes have not been used previously. This can be minimized by effective use of advance guide signing and pavement markings.

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EXHIBIT V-14 (Continued)
Strategy Attributes for Providing Offset Right-Turn Lanes at Intersections (T)

	When installation of offset right-turn lanes increases the overall width of the intersection, the additional width may cause potential problems for pedestrians crossing the intersection. A possible solution to this problem would be to provide a pedestrian refuge island between the offset right-turn lane and through lanes.
Appropriate Measures and Data	Key *process measures* include the *number of intersection approaches for which offset right-turn lanes are implemented* and the *number of conflicts affected by the improvements.* *Crash frequency and severity* are key safety effectiveness measures. Separate analysis of the crash types targeted by the improvement (see above) is desirable. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crashes and crashes related to targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	Public information and education programs about the operation of offset right-turn lanes and their potential safety benefits should be considered when such treatments are used for the first time in a given area. Such programs can be useful in familiarizing drivers with the intended operation of offset right-turn lanes.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Highway agencies should consider the adoption of offset right-turn lanes as standard practice for typical highway intersection designs. Nearly any highway agency can make use of this strategy. While the strategy is potentially applicable to rural, urban, and suburban areas, its primary application is on urban and suburban arterials. There is no formal policy guidance on the use of offset right-turn lanes in the AASHTO *Policy on Geometric Design of Highways and Streets.* Highway agencies may consider incorporating it in their own design manuals and guides.
Issues Affecting Implementation Time	The implementation period for provision of offset right-turn lanes is 2 to 4 years. Intersections at which offset right-turn lanes can be provided simply by restriping the roadway are relatively rare. Therefore, time for project development and construction is required. Where an existing right-turn lane and wide shoulder are present, offset right-turn lanes can usually be provided without purchasing additional right-of-way; in such cases, implementation in 2 years may be possible. If additional right-of-way is needed and substantial social and environmental impacts need to be evaluated, the implementation may take up to 4 years. The implementation period can be reduced where an agency adopts this design by policy and implements it on projects in preliminary or final design.
Costs Involved	Costs may be highly variable and depend largely on the existing right-of-way.
Training and Other Personnel Needs	Effective use of offset right-turn lanes should be addressed in highway agency training concerning access management and intersection operation.
Legislative Needs	None identified.

EXHIBIT V-14 (Continued)
Strategy Attributes for Providing Offset Right-Turn Lanes at Intersections (T)

Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

Strategy 17.1 B9—Provide Right-Turn Acceleration Lanes at Intersections (T)

General Description

Drivers turning onto an uncongested highway accelerate until the desired open-road speed is reached. When acceleration by entering traffic takes place directly on the traveled way, it may disrupt the flow of through-traffic. To minimize this operational problem due to right-turning traffic at divided highway intersections, right-turn acceleration lanes may be used. An acceleration lane is an auxiliary or speed-change lane that allows vehicles to accelerate to highway speeds before entering the through-traffic lanes of a highway. Acceleration lanes should be of sufficient length to permit adjustments in speeds of both through and entering vehicles so that the driver of the entering vehicle can position the vehicle opposite a gap in the through-traffic stream and maneuver into that gap before reaching the end of the acceleration lane.

EXHIBIT V-15
Strategy Attributes for Providing Right-Turn Acceleration Lanes at Intersections (T)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections that experience a high proportion of rear-end collisions related to the speed differential caused by vehicles making a right-turn maneuver onto the highway.
Expected Effectiveness	By removing the slower right-turning vehicles from the through lanes, this strategy is expected to reduce rear-end and sideswipe collisions resulting from conflicts between vehicles making a right-turn maneuver onto the highway and through vehicles on the highway. Research has shown that right-turn acceleration lanes at intersections function effectively and do not create safety problems (Harwood et al., 1995). However, no quantitative estimates of the safety effectiveness of right-turn acceleration lanes at intersections are available. Further research to provide quantitative estimates of the safety effectiveness of right-turn acceleration lanes at intersections is needed.

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EXHIBIT V-15 (Continued)
Strategy Attributes for Providing Right-Turn Acceleration Lanes at Intersections (T)

Key to Success	A key to success in providing right-turn acceleration lanes is to make sure that they are operationally warranted by relatively high right-turn volumes or justified on the basis of an existing pattern of rear-end or sideswipe collisions related to right-turn maneuvers.
Potential Difficulties	If a right-turn acceleration lane is excessively long or poorly marked, through drivers may mistake it for an additional through lane. There is little guidance available on the best geometric design for right-turn acceleration lanes. Both parallel and tapered acceleration-lane designs have been used. The AASHTO *Policy on Geometric Design for Highways and Streets* provides guidance on the design of acceleration lanes for freeway entrance ramps, but there is not specific design guidance for acceleration lanes at intersections. When installation of right-turn acceleration lanes increases the overall width of the intersection, the additional width may cause potential problems for pedestrians crossing the intersection. One possible solution to this problem is to provide a pedestrian refuge island in the median.
Appropriate Measures and Data	Key *process measures* include the *number of intersection departure roadways on which acceleration lanes are provided* and the *number of conflicts eliminated by the improvement.* *Crash frequency and severity, by type,* are key safety effectiveness measures. It is especially useful to identify crashes related to right turns onto the highway and analyze them separately. Crash frequency and severity data are needed to evaluate such improvements. If feasible, both total crash and rear-end and sideswipe crashes related to the targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure. Additional key traffic volume data include right-turn volumes, through volumes, and vehicle mix.
Associated Needs	Most drivers understand right-turn acceleration lanes and use them correctly. Where right-turn acceleration lanes are first introduced in an area, a public information and education campaign to explain their proper use may be desirable. The focus of such a campaign should generally be on how to properly enter the acceleration lane from the minor road.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that their design policies for new or reconstructed intersections incorporate provision of right-turn acceleration lanes. Highway agencies should review their traffic engineering and design policies regarding right-turn acceleration lanes to ensure that appropriate action is being taken on routine projects. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.
Issues Affecting Implementation Time	Time for implementation of right-turn acceleration lanes at intersections may vary from 3 months to 4 years. At some locations, right-turn acceleration lanes can be constructed simply by restriping the roadway. At other locations, widening the roadway, cutting further into a shoulder, or acquiring additional right-of-way may be needed. Such projects may require a substantial time for development and construction. Where additional right-of-way is required or where the environmental process requires analysis and documentation, project implementation may take up to 4 years.

EXHIBIT V-15 (Continued)
Strategy Attributes for Providing Right-Turn Acceleration Lanes at Intersections (T)

Costs Involved	Costs are highly variable. Where sufficient roadway or shoulder width to provide a right-turn acceleration lane is available, it may be possible to provide a right-turn acceleration lane at moderate cost. Where additional right-of-way must be acquired, higher costs are likely.
Training and Other Personnel Needs	Right-turn acceleration lanes at intersections should be included in highway agency training concerning geometric design.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

NCHRP Report 279: Intersection Channelization Design Guide (Neuman, 1985), Transportation Research Board of the National Academies.

NCHRP Report 375: Median Intersection Design (Harwood et al., 1995), Transportation Research Board of the National Academies, 1995.

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

Strategy 17.1 B10—Provide Full-Width Paved Shoulders in Intersection Areas (T)

General Description

Well-designed and properly maintained shoulders in intersection areas provide

- Space for the motorist to avoid potential accidents or reduce accident severity,
- Improved lateral placement of vehicles and space for encroachment of vehicles,
- Space for pedestrian and bicycle use, and
- Space to park disabled vehicles out of the traveled way.

Furthermore, the sense of openness created by shoulders of adequate width contributes to driving ease and freedom from strain. Finally, full-width shoulders can be used for temporary storage of snow that is plowed from the road during times of heavy snowfall, allowing the full width of the lanes to be available for moving traffic and minimizing the potential sight obstruction of plowed snow.

EXHIBIT V-16
Strategy Attributes for Providing Full-Width Paved Shoulders in Intersection Areas (T)

Technical Attributes

Target	The target for this strategy should be unsignalized intersections on divided highways with no shoulder or shoulder widths smaller than 8 feet that experience a high proportion of run-off-road accidents as a result of avoidance maneuvers or a high proportion of rear-end accidents that could have been avoided had a full-width paved shoulder been provided.
Expected Effectiveness	The published literature on the safety effectiveness of shoulder widening and paving deals primarily with shoulders with roadway segments rather than shoulders at intersections. In *TRB State-of-the-Art Report 6* (1987), Zegeer and Deacon reviewed more than 30 articles and reports related to the effect of lane width, shoulder width, and shoulder type on highway safety. They concluded that the expected reduction in run-off-road and opposite-direction accidents from shoulder-widening projects ranged from 6 to 21 percent, depending upon the amount of widening. Recently, a group of experts convened for an FHWA study and concluded from a review of literature that shoulder widening on higher-volume two-lane roadways reduces total crashes by 2.8 percent per foot of additional shoulder width. This expert panel also concluded that there is a small safety benefit to paving existing unpaved shoulders. The magnitude of this benefit increases with increasing shoulder width (Harwood et al., 2000). The results of these studies are not directly applicable to quantify the safety effectiveness of providing full-width paved shoulders at intersections. However, the results do provide an indication that providing full-width paved shoulders at intersections may improve safety. In addition, when Bauer and Harwood (1996) developed statistical models of at-grade intersection accidents, they found that increased lane widths and increased shoulder widths lowered the probability of serious crashes and/or multiple-vehicle crashes at unsignalized urban intersections. Thus, further research to quantify safety effectiveness of providing full-width paved shoulders at intersections is desirable.
Key to Success	The key to success in providing full-width paved shoulders is to make sure that they are operationally justified on the basis of an existing accident pattern.
Potential Difficulties	There are three potential difficulties associated with this strategy. The first difficulty concerns recognizing an accident pattern for which this strategy is applicable. This may require reviewing police accident reports to determine why a vehicle ran off the road or whether a rear-end accident could have been avoided had a shoulder been present. Second, vehicles turning right may use a full-width shoulder as a pseudo right-turn lane, which may or may not be desirable. Third, when providing full-width paved shoulders increases the overall width of the intersection, the additional width may cause potential problems for pedestrians crossing the intersection. One possible solution to this third issue is to provide a pedestrian refuge island in the median.
Appropriate Measures and Data	Key process measures include the number of intersection approaches for which shoulders are improved to full-width paved shoulders. Crash frequency and severity, by type, are key safety effectiveness measures. It is especially useful to identify run-off-road and rear-end crashes related to inadequate shoulders and analyze them separately. Crash frequency and severity data are needed for evaluation of such improvements. If feasible, both total crashes and run-off-road and rear-end crashes at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	None identified.

EXHIBIT V-16 (Continued)
Strategy Attributes for Providing Full-Width Paved Shoulders in Intersection Areas (T)

Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that, where appropriate, their design policies for new or reconstructed intersections incorporate provision of full-width paved shoulders. Highway agencies should review their traffic engineering and design policies regarding the provision of full-width paved shoulders to ensure that appropriate action is being taken on routine projects. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.
Issues Affecting Implementation Time	Implementing this strategy may take from 3 months to 4 years. At some locations, full-width shoulders are already provided and simply need to be paved. At other locations, acquisition of additional right-of-way may be needed. Where right-of-way is required or where the environmental process requires analysis and documentation, project design and implementation periods can become lengthy.
Costs Involved	Costs are highly variable. Where paving an existing full-width shoulder is possible, the costs are relatively low. Costs may be moderate where both grading and paving are needed. Higher costs will be incurred where right-of-way must be acquired.
Training and Other Personnel Needs	None identified.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

FHWA-RD-96-125, *Statistical Models of At-Grade Intersection Accidents* (Bauer and Harwood, 1996).

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

NCHRP Report 254: Shoulder Geometrics and Use Guidelines (Downs and Wallace, 1982), Transportation Research Board of the National Academies.

TRB State-of-the-Art Report 6: Effect of Lane Width, Shoulder Width, and Shoulder Type on Highway Safety (Zegeer and Deacon, 1987), Transportation Research Board of the National Academies.

Strategy 17.1 B11—Restrict or Eliminate Turning Maneuvers by Signing (T)

General Description

Safety at some unsignalized intersections can be enhanced by restricting turning maneuvers, particularly left turns, during certain periods of the day (such as peak traffic periods) or by prohibiting particular turning movements altogether. Turn restrictions and prohibitions can be implemented by signing.

EXHIBIT V-17
Strategy Attributes for Restricting or Eliminating Turning Maneuvers by Signing (T)

Technical Attributes	
Target	The target for this strategy is unsignalized intersections with patterns of crashes related to particular turning maneuvers where it is impractical to reduce that pattern of crashes by improving sight distance or providing a left-turn or shoulder bypass lane.
Expected Effectiveness	Turn restrictions or prohibitions should reduce crashes related to the affected turning maneuver by nearly 100 percent during the period for which the restriction or prohibition is in effect. However, a complete assessment of the effect of a turn restriction or prohibition on safety requires consideration of the alternative routes to which the traffic that desires to make the affected turn is diverted and the potential effect of that traffic on the safety performance of that alternative route.
Key to Success	The key to success for this strategy is anticipating the destinations of traffic making the affected turning maneuver and ensuring the availability of alternative routes that can safely accommodate that traffic. It is also important that the turn restriction or prohibition be clearly signed so that motorists become aware of the restriction or prohibition and do not make illegal turns. Signing in conformance with the *Manual on Uniform Traffic Control Devices* (MUTCD) (FHWA, 2000) should be provided. The net effect on safety of turn prohibitions and restrictions is highly site specific and difficult to quantify. However, further research to quantify this effect would be desirable.
Potential Difficulties	A potential pitfall of a turn restriction or prohibition is that suitable alternative routes may not be available, resulting in drivers continuing to make illegal turning maneuvers or taking unanticipated alternative routes through private property or minor local streets. Another potential pitfall occurs where commercial properties are affected and business owners resist the action because of fears of losing business due to restricted access. Finally, experience demonstrates that the effectiveness of turn restrictions is maximized when they are accompanied by physical barriers. Where no such barriers exist and police do not regularly enforce the turning restrictions, violations of turn restrictions may be expected and hence the safety effectiveness degraded. See Strategy 17.1 B11.
Appropriate Measures and Data	*Key process measures* are *the number of intersection approaches for which turn restrictions are implemented* and *the number of potential conflicts eliminated by the improvements.* *Crash frequency and severity, by type,* are key safety effectiveness measures. Separate analysis of crashes targeted by the improvement is desirable. Where issues of potential effect on commercial operations exist, performance measures may be needed that reflect the change in sales or changes in other measures of economic activity.

EXHIBIT V-17 (Continued)
Strategy Attributes for Restricting or Eliminating Turning Maneuvers by Signing (T)

	Crash frequency and severity data are needed. If feasible, both total crashes and crashes related to restricted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure. In addition, it will be useful, when planning the improvements, to estimate traffic conflicts due to the turning movements to be restricted. In some cases, sales and other economic data may be needed to assess impacts on commercial operations whose access is affected.
Associated Needs	Public information and education about the need for the turn prohibition and the availability of alternative routes should be part of any turn restriction or prohibition project.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that, where appropriate, their traffic operational policies provide for prohibition or restriction of turns. Highway agencies should review their traffic engineering policies related to intersection operations to ensure that turn prohibitions are considered in routine intersection reviews. Nearly any highway agency can participate in implementing this strategy. While it is applicable to both rural and urban locations, it is most appropriate on urban and suburban arterials.
Issues Affecting Implementation Time	Since turn prohibitions are normally implemented by signing, they can be implemented quickly, often within 3 months or less.
Costs Involved	Since this strategy is implemented through signing, its cost is low.
Training and Other Personnel Needs	Turn prohibitions and restrictions should be addressed in highway agency training concerning traffic control devices.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections. It is intended as an alternative to provision of left-turn lanes or shoulder bypass lanes, so it is not appropriate for use in conjunction with those strategies. A traffic law enforcement program in coordination with the restrictions, especially following their introduction, is also desirable.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

Strategy 17.1 B12—Restrict or Eliminate Turning Maneuvers by Providing Channelization or Closing Median Openings (T)

General Description

Safety at some unsignalized intersections can be enhanced by prohibiting particular turning movements altogether with the use of channelization or by closing median openings.

EXHIBIT V-18
Strategy Attributes for Restricting or Eliminating Turning Maneuvers by Providing Channelization or Closing Median Openings (T)

Technical Attributes	
Target	The target for this strategy is unsignalized intersections with patterns of crashes related to particular turning maneuvers where it is impractical to reduce that pattern of crashes by improving sight distance or providing a left-turn or shoulder bypass lane. This strategy is applicable at locations where it is possible to restrict or eliminate turning maneuvers by providing channelization or by closing the median opening.
Expected Effectiveness	Turn restrictions or prohibitions should reduce crashes related to the affected turning maneuver by nearly 100 percent at the locations where the restriction or prohibition is in effect. However, a complete assessment of the effect of a turn restriction or prohibition on safety requires consideration of the alternative routes to which the traffic that desires to make the affected turn is diverted and the potential effect of that traffic on the safety performance of that alternative route. Adequate evaluations of this type have not been found.
Key to Success	The key to success for this strategy is anticipating the destinations of traffic making the affected turning maneuver and ensuring that alternative routes that can safely accommodate that traffic are available. It is also important that the turn restriction or prohibition be clearly signed so that motorists become aware of the restriction or prohibition and do not make illegal turns. Furthermore, it will be important to include all stakeholders in the early planning stages, especially any business properties for which access may be made less convenient for customers.
Potential Difficulties	A potential pitfall of a turn restriction or prohibition is that suitable alternative routes may not be available, resulting in drivers taking unanticipated alternative routes through private property or minor local streets. Another potential pitfall occurs where commercial properties are affected and business owners resist the action because of fears of losing business. A difficulty with this strategy is that it commits the agency to prohibition of turning movements 100 percent of the time (i.e., this strategy should not be employed to treat temporal or short-lived problems).
Appropriate Measures and Data	Key *process measures* are the *number of intersection approaches for which turn restrictions are implemented* and the *number of potential conflicts eliminated by the improvements.*

EXHIBIT V-18 (Continued)
Strategy Attributes for Restricting or Eliminating Turning Maneuvers by Providing Channelization or Closing Median Openings (T)

	Crash frequency and severity, by type, are key safety effectiveness measures. Separate analysis of crashes targeted by the improvement is desirable. Where issues of potential effect on commercial operations exist, performance measures may be needed that reflect the number of properties affected, the change in sales, or changes in other measures of economic activity. Crash frequency and severity data are needed. If feasible, both total crashes and crashes related to restricted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure. In addition, it will be useful when planning the improvements to estimate traffic conflicts due to the turning movements to be restricted. In some cases, sales and other economic data may be needed to assess impacts on commercial operations whose access is affected.
Associated Needs	Public information and education about the need for the turn prohibition and the availability of alternative routes should be part of any turn restriction or prohibition project. A traffic law enforcement program in coordination with the restrictions, especially following their introduction, is also desirable.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that, where appropriate, their traffic operational policies provide for prohibition or restriction of turns. Highway agencies should review their traffic engineering policies related to intersection operations to ensure that turn prohibitions are considered in routine intersection reviews. Nearly any highway agency can participate in implementing this strategy. While it is applicable to both rural and urban locations, it is most appropriate on urban and suburban arterials.
Issues Affecting Implementation Time	Turn prohibitions that are implemented by closing a median opening can be implemented quickly, often within 3 months or less. Turn prohibitions requiring the installation of channelization may take from 3 months to 1 year to implement.
Costs Involved	The cost of this strategy will depend on the treatment. Closing a median opening is considerably less costly than installing channelization.
Training and Other Personnel Needs	Turn prohibitions and restrictions should be addressed in highway agency training. Considerations such as impact on travel patterns, accident migration, and impact on adjacent properties should be covered.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections. It is intended as an alternative to providing left-turn lanes or shoulder bypass lanes, so it is not appropriate for use in conjunction with those strategies.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Median Handbook (Florida Department of Transportation, 1997).

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

NCHRP Report 420: Impacts of Access Management Techniques (Gluck, Levinson, and Stover, 1999), Transportation Research Board of the National Academies.

Strategy 17.1 B13—Close or Relocate "High-Risk" Intersections (T)

General Description

For some unsignalized intersections with crash histories, the best method of improving safety may be to close or relocate the intersection. This is a radical approach to safety improvement that should generally be considered only when less restrictive measures have been tried and have failed. Intersection relocation can be accomplished by realigning the minor-road approaches so that they intersect the major road at a different location or a different angle. Intersection closure can be accomplished by closing and abandoning the intersecting minor streets or by converting those minor streets so that they dead-end before reaching their former intersection with the major street.

EXHIBIT V-19
Strategy Attributes for Closing or Relocating High-Risk Intersections (T)

Technical Attributes	
Target	The target of this strategy should be unsignalized intersections with high levels of intersection-related crashes that other strategies have not been successful in reducing or for which other strategies are not considered appropriate. This strategy may also be used at locations where a particular strategy such as installing a turn lane or increasing sight distance is impractical at the current location, but could be applied if the intersection were moved.
Expected Effectiveness	Closure of an intersection should eliminate crashes at that location. Consideration must be given to the adjacent intersections and to alternative routes onto which traffic would be diverted and the potential impact of safety on those routes. Further research to quantify the effectiveness of this strategy would be desirable.
Key to Success	The key to success for a project of this type is involving the affected neighborhood early in the decision-making process to develop and maintain support for the project.
Potential Difficulties	Diverted traffic may contribute to safety problems at adjacent intersections or on alternative routes, resulting in no net benefit. Owners of properties where access would be reduced, especially commercial operations, may oppose this strategy. Temporary unsafe conditions may occur immediately after the change due to erratic maneuvers by drivers whose expectancy has been violated. Care should be taken during the transition period, both before and after the change is made, to alert drivers to the changes as they approach the section involved.

EXHIBIT V-19 (Continued)
Strategy Attributes for Closing or Relocating High-Risk Intersections (T)

Appropriate Measures and Data	Key *process measures* are the *number of intersections eliminated or relocated* and the *change in the number of conflicts due to closure or relocation.* *Crash frequency and severity, by type,* are key safety effectiveness measures. Separate analysis of crashes targeted by such intersection relocations is desirable. Where issues of potential effect on commercial operations exist, impact measures may be needed that reflect the change in sales or other measures of economic activity. Crash frequency and severity data are needed for the existing and relocated intersections. Traffic volume data are needed to represent exposure. In some cases, sales and other economic data may be needed to assess impacts on commercial operations whose access is affected.
Associated Needs	Public information and education are central to successful use of this strategy.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agency policies concerning geometric design of intersections should address the appropriate application and potential benefits of intersection relocations. Nearly any highway agency can participate in the implementation of this strategy. While the strategy is applicable to both rural and urban locations, the greatest need is for agencies that operate extensive systems of urban and suburban arterials.
Issues Affecting Implementation Time	This strategy requires an implementation time of 1 to 4 years. At least 1 year is necessary to work out the details of street relocation or closure and to communicate the plan to affected businesses and residents. Where relocation requires right-of-way acquisition and/or demolition of existing structures, an extensive project development process up to 4 years long may be required.
Costs Involved	Costs to implement this strategy are highly variable. Where mere closure of an existing intersection is all that is needed, costs are low. In other cases, construction of a new intersection or diversion of traffic to a different existing intersection may require substantially higher expenditures. Potential funding sources include state or local highway agencies.
Training and Other Personnel Needs	Use of this technique should be included in training concerning geometric design issues.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	Closure of an intersection is an alternative to other strategies for improving safety and is not typically used in conjunction with other strategies. Relocation of an intersection is nearly always used in conjunction with most other strategies for improving safety. Indeed, in many cases, the purpose of relocating an intersection may be to make those other strategies feasible.
Other Key Attributes to a Particular Strategy	This strategy is primarily appropriate for urban and suburban intersections where reasonable alternative access or routes are readily available.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Washington, D.C. (2001).

NCHRP Report 420: Impacts of Access Management Techniques (Gluck, Levinson, and Stover, 1999), Transportation Research Board of the National Academies.

Strategy 17.1 B14—Convert Four-Legged Intersections to Two T-Intersections (T)

General Description

For some unsignalized four-legged 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. This conversion to two T-intersections can be accomplished by separating the two cross-street approaches an appreciable distance along the major road, thus creating two separate T-intersections that operate independently of one another.

EXHIBIT V-20
Strategy Attributes for Converting Four-Legged Intersections to Two T-Intersections (T)

Technical Attributes	
Target	The strategy targets unsignalized four-legged intersections with very low through volumes on the cross street.
Expected Effectiveness	In a study conducted by Hanna et al. (1976), offset intersections had accident rates that were approximately 43 percent of the accident rate at comparable four-legged intersections. Thus, it is expected that this strategy would reduce the accident experience of targeted four-legged intersections.
Key to Success	The success of this strategy depends upon the through volume of the cross street. If through volumes are high, the intersection may be safer if left as a conventional four-legged intersection. Converting it to two T-intersections would only create excessive turning movements at each of the T-intersections.
Potential Difficulties	A potential difficulty with this strategy is the spacing between the two T-intersections. If the two intersections are not spaced far enough apart, two problems can occur. First, there may not be enough storage length for the left-turning vehicles between the two intersections. Second, the operations of the two intersections may interfere with one another. Another difficulty may occur in providing safe access to the properties adjacent to the existing four-legged intersection.
Appropriate Measures and Data	Key *process measures* are the *number of intersections that have been converted to two T-intersections* and the *change in the number of conflicts due to this improvement.* *Crash frequency and severity, by type,* are key safety effectiveness measures. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure. In addition, it will be useful, when planning the improvements, to estimate traffic conflicts involving the increase in turning movements caused by through traffic on the cross street.

EXHIBIT V-20 (Continued)
Strategy Attributes for Converting Four-Legged Intersections to Two T-Intersections (T)

Associated Needs	None identified.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that, where appropriate, their geometric design policies provide for this strategy. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy requires an implementation time of 1 to 4 years. At least 1 year is necessary to work out the details of intersection approach relocation and to communicate the plan to affected businesses and residents. Where relocation requires right-of-way acquisition and/or demolition of existing structures, an extensive project development process up to 4 years in duration may be required.
Costs Involved	Converting a conventional four-legged intersection to two T-intersections involves the realignment of at least one intersection approach. The cost of this type of construction project is usually high. Furthermore, additional right-of-way will generally need to be acquired.
Training and Other Personnel Needs	Appropriate uses of this strategy should be included in geometric design training for highway agency personnel.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	The conversion of a conventional four-legged intersection to two T-intersections may be used in conjunction with most other strategies for improving safety. Indeed, in many cases, the relocation of an intersection approach may be done to make those other strategies feasible.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Transportation Research Record 601, "Characteristics of Intersection Accidents in Rural Municipalities" (Hanna, Flynn, and Tyler, 1976), Transportation Research Board of the National Academies.

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Washington, D.C. (2001).

Strategy 17.1 B15—Convert Offset T-Intersections to Four-Legged Intersections (T)

General Description

For some unsignalized offset T-intersections with very high through volumes on the cross street, the best method of improving safety may be to convert the intersection to a single four-legged intersection. This conversion to a four-legged intersection can be accomplished by realigning the two cross-street approaches to meet at a single point along the major road, thus creating one four-legged intersection.

EXHIBIT V-21
Strategy Attributes for Converting Offset T-Intersections to Four-Legged Intersections (T)

Technical Attributes	
Target	The strategy targets unsignalized offset T-intersections, at which through volumes on the cross street are very high.
Expected Effectiveness	It is expected that this strategy would reduce accidents involving left-turning traffic from the major road onto the cross street at each of the two T-intersections. It can reduce or eliminate safety problems associated with insufficient spacing between existing offset T-intersections.
Key to Success	The success of this strategy depends upon the through volume of the cross street. If through volumes are low, the intersection may be safer if left as two offset T-intersections. Two offset T-intersections with low cross-street through volumes are generally safer than a four-legged intersection.
Potential Difficulties	There should be no potential difficulties with this strategy as long as the resulting four-legged intersection is properly designed and traffic control devices are properly used.
Appropriate Measures and Data	Key process measures are *the number of intersections that have been converted from offset T-intersections to four-legged intersections* and *the reduction in the number of conflicts due to this improvement.* *Crash frequency and severity, by type,* are key safety effectiveness measures. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	None identified.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that, where appropriate, their geometric design policies provide for this strategy. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy requires an implementation time of 1 to 4 years. At least 1 year is necessary to work out the details of intersection approach relocation and to communicate the plan to affected businesses and residents. Where relocation requires right-of-way acquisition and/or demolition of existing structures, an extensive project development process up to 4 years long may be required.
Costs Involved	Converting two offset T-intersections to a conventional four-legged intersection involves the realignment of at least one intersection approach. The cost of this type of construction project is usually high. Furthermore, additional right-of-way will generally need to be acquired.
Training and Other Personnel Needs	Appropriate uses of this strategy should be included in geometric design training for highway agency personnel.

EXHIBIT V-21 (Continued)
Strategy Attributes for Converting Offset T-Intersections to Four-Legged Intersections (T)

Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	The conversion of two offset T-intersections to a conventional four-legged intersection may be used in conjunction with most other strategies for improving safety. Indeed, in many cases, the purpose of relocating an intersection approach may be to make those other strategies feasible.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Washington, D.C. (2001).

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

Strategy 17.1 B16—Realign Intersection Approaches to Reduce or Eliminate Intersection Skew (P)

General Description

When roadways intersect at skewed angles, the intersections may experience one or more of the following problems:

- Vehicles may have a longer distance to traverse while crossing or turning onto the intersecting roadway, resulting in an increased time of exposure to the cross-street traffic.
- Older drivers may find it more difficult to turn their head, neck, or upper body for an adequate line of sight down an acute-angle approach.
- The driver's sight angle for convenient observation of opposing traffic and pedestrian crossings is decreased.
- Drivers may have more difficulty aligning their vehicles as they enter the cross street to make a right or left turn.
- Drivers making right turns around an acute-angle radius may encroach on lanes intended for oncoming traffic from the right.
- The larger intersection area may confuse drivers or cause them to deviate from the intended path.
- Through-roadway drivers making left turns across an obtuse angle may attempt to maintain a higher than normal turning speed and cut across the oncoming traffic lane on the intersecting street.

- The vehicle body may obstruct the line of sight of drivers with an acute-angle approach to their right.

Realignment of intersection approaches to reduce or eliminate intersection skew may be desirable to improve safety at a skewed intersection.

EXHIBIT V-22
Strategy Attributes for Realigning Intersection Approaches to Reduce or Eliminate Intersection Skew (P)

Technical Attributes	
Target	The strategy is targeted to reduce the frequency of collisions resulting from insufficient intersection sight distance and awkward sight lines at a skewed intersection.
Expected Effectiveness	A group of experts convened for a recent FHWA study concluded from a review of the literature that realigning intersection approaches to reduce or eliminate intersection skew improves safety at unsignalized intersections (Harwood et al., 2000). The expert panel concluded the safety effectiveness of realignment to be as follows: AMF = exp (0.0040 SKEW) For three-legged intersections and AMF = exp (0.0054 SKEW) For four-legged intersections where: AMF = Accident modification factor SKEW = Intersection skew angle (degrees), expressed as the absolute value of the difference between 90 degrees and the actual intersection angle.
Key to Success	A key to success in realigning a skewed intersection is identifying candidate locations at which there exist crash patterns related to the intersection angle. Any intersection with a pattern of right-angle or turning collisions should be checked to determine whether the skew angle of the intersection is contributing to these collisions.
Potential Difficulties	When realigning a skewed intersection approach, it is possible to create such a sharp horizontal curve that the curve itself becomes a safety concern. Thus, the designer should be alert to avoid trading one safety concern for another. Realignment may negatively affect adjacent properties.
Appropriate Measures and Data	A key process measure is the number of skewed intersection approaches that have been realigned. Crash frequency and severity, by type, are key safety effectiveness measures. Separate analysis of crashes targeted by the improvement is desirable. Crash frequency and severity data are needed. If feasible, both total crashes and crashes related to the improvement should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	None identified.

EXHIBIT V-22 (Continued)
Strategy Attributes for Realigning Intersection Approaches to Reduce or Eliminate Intersection Skew (P)

Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that their design policies for new or reconstructed intersections incorporate the reduction or elimination of skew angle. Highway agencies should review their traffic engineering and design policies concerning the reduction or elimination of skew angle. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy requires an implementation time of 1 to 4 years. At least 1 year is necessary to work out the details of intersection approach realignment and to communicate the plan to affected businesses and residents. Where relocation requires right-of-way acquisition and/or demolition of existing structures, an extensive project development process up to 4 years long may be required.
Costs Involved	Reducing or eliminating the skew angle of an intersection involves the realignment of at least one intersection approach. The cost of this type of construction project is usually high. Furthermore, additional right-of-way will generally need to be acquired.
Training and Other Personnel Needs	None identified.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	Reducing or eliminating the skew angle of an intersection may be done in conjunction with most other strategies for improving safety. Indeed, in many cases, the purpose of realigning an intersection approach may be to make those other strategies feasible.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Washington, D.C. (2001).

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

Nebraska Department of Roads, *Guidelines for Realignment of Skewed Intersections: Final Report* (McCoy, Tripi, and Bonneson, 1994).

Transportation Research Record 1612, "Intersection Angle Geometry and the Driver's Field of View" (Gattis and Low, 1998), Transportation Research Board of the National Academies.

Strategy 17.1 B17—Use Indirect Left-Turn Treatments to Minimize Conflicts at Divided Highway Intersections (T)

General Description

Many intersection operational and safety problems at two-lane and divided-highway intersections can be traced to difficulties of accommodating left-turn demand. Such difficulties involve both demand volume and the frequency of demand along a corridor. Furthermore, vehicles that slow down or stop to turn left in a lane used primarily by through traffic increase the potential for rear-end collisions. One way to address the impacts of such left-turn movements is the use of indirect left-turn treatments. Indirect left-turn treatments include the use of jug-handle roadways before the crossroad, loop roadways beyond the crossroad, and directional median crossovers beyond the crossroad. Indirect left-turn treatments enable drivers to make left turns efficiently on divided highways, including highways with relatively narrow medians.

EXHIBIT V-23
Strategy Attributes for Using Indirect Left-Turn Approaches to Minimize Conflicts at Divided Highway Intersections (T)

Technical Attributes	
Target	This strategy targets unsignalized intersections with operational and safety problems that can be traced to difficulties of accommodating left-turn demand.
Expected Effectiveness	It is expected that this strategy will reduce (1) rear-end collisions resulting from the conflict between vehicles waiting to turn left and following vehicles and (2) right-angle collisions resulting from the conflict between vehicles turning left and oncoming through vehicles. In a related effort, a study for the National Cooperative Highway Research Program (NCHRP) Project 17–21 is assessing the safety of U-turns at unsignalized median openings.
Key to Success	A key to success in implementing indirect left turns is to make sure that this strategy is justified on the basis of high left-turn demand or an existing pattern of left-turn collisions. Another key to success for a project of this type is involving the affected adjacent property owners and residents in the decision-making process to develop and maintain support for the project.
Potential Difficulties	Diverted traffic may contribute to safety problems at adjacent intersections or on alternative routes, resulting in no net benefit. Owners of properties where access would be reduced, especially commercial operations, may oppose this strategy. Thus, careful evaluation of the potential impacts of proposed improvements is needed to avoid or minimize such problems. A temporary hazard may exist during the transition period after the change is opened to traffic. Advanced notification of drivers is important, both in terms of notification prior to instituting the change and in signing that provides the appropriate notice of a change.
Appropriate Measures and Data	Process measures include the number of intersections at which the movements are altered and the change in the number of conflicts, by type. Crash frequency and severity are by type key safety effectiveness measures. It is especially useful to identify crashes related to left turns and analyze them separately. Where issues of potential effect on commercial operations exist, impact measures may be needed that reflect the change in sales or changes in other economic activity.

EXHIBIT V-23 (Continued)
Strategy Attributes for Using Indirect Left-Turn Approaches to Minimize Conflicts at Divided Highway Intersections (T)

	Crash frequency and severity data are needed. If feasible, both total crashes and rear-end crashes related to targeted turning movements at the intersection should be analyzed separately. Traffic volume data are needed to represent exposure. In addition, it will be useful, when planning the improvements, to estimate traffic conflicts. In some cases, sales and other economic data may be needed to assess impacts on commercial operations whose access is affected.
Associated Needs	There is a definite need to inform the public, especially adjacent property owners, about the benefits of access management techniques and about methods to mitigate the adverse effects on access restrictions.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that their design policies for new or reconstructed intersections incorporate provision of indirect left turns. Highway agencies should review their traffic engineering and design policies regarding use of indirect left turns. Nearly any highway agency can participate in implementing this strategy, which is applicable to rural, urban, and suburban areas.
Issues Affecting Implementation Time	Implementation time can vary from 3 months to 4 years. At some locations, indirect left turns can be implemented simply by appropriate signing. Other locations may require major reconstruction. Such projects require a substantial time for development and construction. Where right-of-way is required or where the environmental process requires analysis and documentation, the time will be longer.
Costs Involved	Costs are highly variable. Where an improvement can be implemented by signing an existing roadway, the costs are nominal. Where reconstruction is necessary, costs over $100,000 per intersection approach may be incurred. Potential funding sources include federal, state, and local highway agencies.
Training and Other Personnel Needs	Appropriate uses of this strategy should be included in geometric design training for highway agency personnel.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	Optimal operation and safety of indirect left turns requires appropriate design and signing.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Washington, D.C. (2001).

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

Strategy 17.1 B18—Improve Pedestrian and Bicycle Facilities to Reduce Conflicts between Motorists and Nonmotorists (Varies)

General Description

Nearly one-third (32.2 percent) of all pedestrian-related crashes occur at or within 50 feet of an intersection. Of these, 30 percent involve a turning vehicle. Another 22 percent of pedestrian crashes involve a pedestrian either running across the intersection or darting out in front of a vehicle whose view was blocked just prior to the impact. Finally, 16 percent of these intersection-related crashes occur because of a driver violation (e.g., failure to yield right-of-way). Improvements to pedestrian facilities (short of grade separation) that may reduce conflicts between motorists and nonmotorists include

- Continuous sidewalks;
- Signed and marked crosswalks;
- Pedestrian signs, signals, and markings;
- Sidewalk set-backs; and
- Lighting.

Some of the problems that bicyclists face at intersections include high traffic volumes and speeds and lack of space for bicyclists. Possible improvement projects include

- Widening the outside through lanes or adding bike lanes,
- Providing median refuges at key minor-street crossings,
- Providing independent bicycle/pedestrian structures where necessary,
- Replacing poorly designed drain grates with bicycle-safe models, and
- Providing smooth paved shoulders.

Further details may be found in the implementation guide for addressing pedestrian crashes. FHWA maintains a site that provides detailed information on pedestrian crash countermeasures at intersections (see http://safety.fhwa.dot.gov/saferjourney/Library/matrix.htm).

EXHIBIT V-24
Strategy Attributes for Improving Pedestrian and Bicycle Facilities to Reduce Conflicts between Motorists and Nonmotorists

Technical Attributes	
Target	This strategy targets unsignalized intersections that experience collisions involving pedestrians and/or bicyclists or that have the potential for such collisions.
Expected Effectiveness	It is expected that improvements to pedestrian and bicycle facilities at unsignalized intersections will reduce the number of collisions between motorists and nonmotorists. Quantitative estimates of effectiveness may exist for some of the countermeasures that may be employed, but not for others. See http://safety.fhwa.dot.gov/saferjourney/Library/matrix.htm for further details.

EXHIBIT V-24 (Continued)
Strategy Attributes for Improving Pedestrian and Bicycle Facilities to Reduce Conflicts between Motorists and Nonmotorists

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, the needs of pedestrians and bicyclists should be anticipated during the design of other intersection improvements, and appropriate improvements should be incorporated in the design before such problems occur. It is desirable to involve groups representing pedestrians and bicyclists in the early stages of a program's development.
Potential Difficulties	Improving pedestrian and bicycle facilities is not a one-time process. The facilities also need to be properly maintained. For example, some issues are often overlooked—a missing or broken section of sidewalk or a construction zone that forces pedestrians to walk in a traffic lane.
Appropriate Measures and Data	The development of effective countermeasures to help prevent pedestrian crashes is hindered by insufficient detail on computerized crash databases. Analysis of these data can provide information on where pedestrian crashes occur (city, street, intersection, two-lane road, etc.), when they occur (time of day, day of week, etc.), and characteristics of the victims involved (age, gender, injury severity, etc.). These data often do not provide a sufficient level of detail regarding the sequence of events leading to the crash. In the 1970s, a methodology for classifying pedestrian crashes was developed by NHTSA to better define the sequence of events and precipitating actions leading to pedestrian–motor vehicle crashes (Snyder and Knoblauch, 1971). In the early 1990s, this method was refined and used to determine the crash types for more than 5,000 pedestrian crashes in California, Florida, Maryland, Minnesota, North Carolina, and Utah (Hunter et al., 1996).
Associated Needs	None identified.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	State and local highway agencies and local agencies should ensure that policies for new roadway construction include pedestrian and bicycle considerations (e.g., provision of sidewalks or shoulders). There are well-organized pedestrian and bicycling organizations that should be considered partners in any planning effort, such as the National Center for Bicycling and Walking (www.walkinginfo.org) and the Pedestrian and Bicycle Information Center (www.bikefed.org).
Issues Affecting Implementation Time	The implementation time for improvements to pedestrian and bicycle facilities is highly variable.
Costs Involved	The cost of improvements to pedestrian and bicycle facilities is highly variable.
Training and Other Personnel Needs	None identified.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	Strategies to reduce pedestrian and bicycle crashes are compatible with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

FHWA-RD-95-163, *Pedestrian and Bicycle Crash Types of the Early 1990s,* Washington, D.C., (Hunter, Stutts, Pein, and Cox, 1996).

FHWA-RD-98-105, *Implementing Bicycle Improvements at the Local Level* (Williams, Burgess, Moe, and Wilkinson, 1998).

FHWA-RD-00-095. *Pedestrian & Bicycle Crash Analysis Tool* (2000).

FH-11-7312, *Pedestrian Safety: The Identification of Precipitating Factors and Possible Countermeasures,* National Highway Traffic Safety Administration (Snyder and Knoblauch, 1971).

Objective 17.1 C—Improve Sight Distance at Unsignalized Intersections

Strategy 17.1 C1—Clear Sight Triangles on Stop- or Yield-Controlled Approaches to Intersections (T)

General Description

Adequate sight distance for drivers at stop- or yield-controlled approaches to intersections has long been recognized as among the most important factors contributing to overall safety at unsignalized intersections. Estimates of the safety effectiveness of providing full intersection sight distance (ISD) where it does not currently exist suggest that up to a 20-percent reduction in related crashes can be expected. Recent research has established design requirements for ISD based upon driver and vehicle functional requirements. *NCHRP Report 383: Intersection Sight Distance* (Harwood et al., 1996) provides design guidelines that have been implemented in the current edition of the AASHTO *Policy on Geometric Design of Highways and Streets* (2001). *NCHRP Report 383* (1996) provides a gap-acceptance-based approach to sight-distance requirements based upon actual driver behavior at intersections. Since, at least at high-speed intersections, the recommended sight distances are shorter than those in previous policies, they are more practical to achieve in the real world. Sight distance improvements can often be achieved at relatively low cost by clearing sight triangles to restore sight distance obstructed by vegetation, roadside appurtenances, or other natural or artificial objects.

EXHIBIT V-25
Strategy Attributes for Clearing Sight Triangles on Stop- or Yield-Controlled Approaches to Intersections (T)

Technical Attributes	
Target	The target should be unsignalized intersections with restricted sight distance and patterns of crashes related to lack of sight distance, where sight distance can be improved by clearing roadside obstructions without major construction.

EXHIBIT V-25 (Continued)
Strategy Attributes for Clearing Sight Triangles on Stop- or Yield-Controlled Approaches to Intersections (T)

Expected Effectiveness	There is no research that adequately quantifies the effectiveness of improving sight distance at unsignalized intersections. A group of safety experts recently reviewed the literature and estimated that if the available sight distance in any quadrant of an intersection is less than or equal to the design sight distance for a speed of 20 km/h less than the actual 85th-percentile speed of the approach, then the frequency of related crashes at the intersection would be increased by 5 percent (Harwood et al., 2000). Thus, a project may be 0 to 20 percent effective in reducing related crashes, depending upon the severity of the existing sight restriction and the number of intersection quadrants affected. Intersection sight-distance-related crashes include angle- and turning-related collisions. Further research to better quantify the safety effectiveness of intersection sight-distance improvements would be desirable.
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.
Potential Difficulties	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.
Appropriate Measures and Data	Key process measures are the number of intersection quadrants in which sight distance was improved and the amount of increase in sight distance achieved. Where issues of potential effect on adjacent properties exist, a process measure may be used to describe this, such as the number of private properties on which alterations were made. Crash frequency and severity, by type, are key safety effectiveness measures. Separate analysis of crashes targeted by the sight distance improvements is desirable. Crash frequency and severity data are needed. If feasible, both total crashes and crash types targeted by the improvement should be analyzed separately. Traffic volume data are needed to represent exposure. A detailed survey of objects in the sight triangle should be made.
Associated Needs	Public information material should be available to landowners to alert them of the safety benefit that will result from keeping corner properties free from sight-restricting plantings and other objects.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	This strategy should be incorporated in highway design policies, highway maintenance manuals, and educational materials for the public. Nearly any highway agency can participate in the implementation of this strategy. Unsignalized intersections with sight distance restrictions in one or more quadrants are common. Since highway maintenance operations are often independent of other safety activities in a highway agency, it is important that both these areas be apprised of the need to protect sight triangles and that there be coordination between them.

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EXHIBIT V-25 (Continued)
Strategy Attributes for Clearing Sight Triangles on Stop- or Yield-Controlled Approaches to Intersections (T)

Issues Affecting Implementation Time	Projects involving clearing sight obstructions on the highway right-of-way can typically be accomplished in 3 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 Involved	Costs will generally be low, assuming that in most cases the objects to be removed are within the right-of-way. Potential funding sources include state and local highway agencies and, to the extent required by law, individual property owners.
Training and Other Personnel Needs	Training concerning removal of sight obstructions near intersections should be included in highway agency training concerning geometric design, highway safety, and highway maintenance.
Legislative Needs	Legal authority of highway agencies to control sight obstructions on private property should be strengthened.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Washington, D.C. (2001).

NCHRP Report 383: Intersection Sight Distance (Harwood, Mason, Brydia, Pietrucha, and Gittings, 1996), Transportation Research Board of the National Academies.

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

Strategy 17.1 C2—Clear Sight Triangles in the Medians of Divided Highways Near Intersections (T)

General Description

Adequate sight distance for drivers at stopped approaches to intersections has long been recognized as among the most important factors contributing to overall safety at unsignalized intersections. A particular concern at divided highway intersections is sight obstructions located in the highway median. Such obstructions can restrict sight distance for drivers of vehicles passing through the median roadway, including through vehicles on the crossroad and vehicles making left turns onto and off of the divided highway. Sight obstructions can include vegetation, roadside appurtenances, or other natural and artificial objects. Since sight obstructions located in the highway median are, almost by definition, located in the highway right-of-way, highway agencies should have direct authority to remove them. If the objects are mature trees or plantings, then environmental issues may arise. For a more detailed discussion of the aspect involving trees, see Volume 3 of this report.

EXHIBIT V-26
Strategy Attributes for Clearing Sight Triangles in the Medians of Divided Highways Near Intersections (T)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections on divided highways with (a) fixed sight obstructions in the median near the intersection and (b) patterns of crashes related to the lack of sight distance.
Expected Effectiveness	There is no research that adequately quantifies the effectiveness of improving sight distance at unsignalized intersections. A group of safety experts recently reviewed the literature and estimated that if the available sight distance in any quadrant of an intersection is less than or equal to the design sight distance for a speed of 20 km/h less than the actual 85th-percentile speed of the approach, then the frequency of related crashes at the intersection would be increased by 5 percent (Harwood et al., 2000). Although this assessment was made for intersections on rural two-lane highways, it appears appropriate to extend it to intersections on divided highway intersections as well. Since the median affects two quadrants on the approach to each side of the divided highway from the median roadway, it is estimated that a project to remove sight obstructions in the median may be 0 to 20 percent effective in reducing related crashes, depending upon the severity of the existing sight restriction and the number of intersection quadrants affected. ISD-related crashes include angle- and turning-related collisions. Further research to better quantify the safety effectiveness of ISD improvements would be desirable.
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.
Potential Difficulties	The difficulties with this strategy primarily relate to public acceptance. From a process and engineering perspective, implementation is relatively straightforward, since, by definition, all work is well within the right-of way. However, most plantings located in medians were deliberately placed there for aesthetic reasons, and the public will often object to their removal, particularly where no site-specific safety problem is evident.
Appropriate Measures and Data	Key process measures are the number of intersection quadrants in which sight distance was improved in the median and the amount of increased sight distance that was achieved. Crash frequency and severity, by type, are key safety effectiveness measures. Separate analysis of crashes targeted by sight distance improvements is desirable. Crash frequency and severity data are needed. If feasible, both total crashes and crash types targeted by the improvement should be analyzed separately. Traffic volume data are needed to represent exposure. A detailed survey of objects in the median should be made.

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EXHIBIT V-26 (Continued)
Strategy Attributes for Clearing Sight Triangles in the Medians of Divided Highways Near Intersections (T)

Associated Needs	Public information material should be available when obstructions to sight distance include trees and mature plantings, the removal of which may involve controversy. The message should include the safety benefit that will result from keeping sight triangles free from sight-restricting plantings.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	This strategy should be incorporated in highway design policies and in highway maintenance manuals. Since highway maintenance operations are often independent of other safety activities in a highway agency, it is important that both these areas be apprised of the need to protect sight triangles and that there be coordination between them. Nearly any highway agency can participate in implementing this strategy.
Issues Affecting Implementation Time	Projects involving clearing sight obstructions on the highway right-of-way can typically be accomplished in 3 months or less, assuming that the objects are readily moveable and their removal is not controversial.
Costs Involved	Costs will generally be low, assuming that in most cases the objects to be removed are within the right-of-way.
Training and Other Personnel Needs	Topics concerning identifying and removing sight obstructions in the median near intersections should be included in highway agency training covering geometric design, highway safety, and highway maintenance.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Washington, D.C. (2001).

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

NCHRP Report 383: Intersection Sight Distance (Harwood, Mason, Brydia, Pietrucha, and Gittings, 1996), Transportation Research Board of the National Academies.

Strategy 17.1 C3—Change Horizontal and/or Vertical Alignment of Approaches to Provide More Sight Distance (T)

General Description

Adequate sight distance for drivers at stopped approaches to intersections has long been recognized as among the most important factors contributing to overall intersection safety. Estimates of the safety effectiveness of providing full ISD where it does not currently occur suggest that up to a 20-percent reduction in related crashes can be expected. Recent research has established design requirements for ISD based on driver and vehicle functional requirements. *NCHRP Report 383: Intersection Sight Distance* (Harwood et al., 1996) provides design guidelines that have been incorporated in the current edition of the AASHTO *Policy on Geometric Design of Highways and Streets* (2001). *NCHRP Report 383* provides a gap-acceptance-based approach to sight distance requirements based on actual driver behavior at intersections. Since, at least at high-speed intersections, the recommended sight distances are shorter than those in previous policies, they are more practical to achieve in the real world. Previous strategies addressed sight distance improvements that can be achieved at relatively low cost by clearing sight triangles to restore sight distance obstructed by vegetation, roadside appurtenances, or other natural or artificial objects. This strategy addresses more costly geometric improvements that involve changing the horizontal or vertical alignment of the intersecting roadways. Such strategies should generally be considered only at intersections with a persistent crash pattern that cannot be ameliorated by less expensive methods.

EXHIBIT V-27
Strategy Attributes for Changing Horizontal and/or Vertical Alignment of Approaches to Provide More Sight Distance (T)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections with restricted sight distance due to horizontal and/or vertical geometry and with patterns of crashes related to that lack of sight distance that cannot be ameliorated by less expensive methods.
Expected Effectiveness	There is no research that adequately quantifies the effectiveness of improving sight distance at unsignalized intersections. A group of safety experts recently reviewed the literature and estimated that if the available sight distance in any quadrant of an intersection is less than or equal to the design sight distance for a speed of 20 km/h less than the actual 85th-percentile speed of the approach, then the frequency of related crashes at the intersection would be increased by 5 percent (Harwood et al., 2000). Thus, a project may be 0 to 20 percent effective in reducing related crashes, depending upon the severity of the existing sight restriction and the number of intersection quadrants affected. ISD-related crashes include angle- and turning-related collisions. Further research to better quantify the safety effectiveness of ISD improvements would be desirable.

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EXHIBIT V-27 (Continued)
Strategy Attributes for Changing Horizontal and/or Vertical Alignment of Approaches to Provide More Sight Distance (T)

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. Because adjacent properties may be affected by the redesign, all the stakeholders should be involved early in the planning process.
Potential Difficulties	The most difficult aspect of this strategy is the potential impact on adjacent property of making improvements to the horizontal or vertical geometry. Because of the potential impacts and the relatively high costs involved, this strategy should generally be considered only when less expensive strategies involving clearing of specific sight obstructions or modifying traffic control devices have been tried and have failed to ameliorate the crash patterns. If additional right-of-way is required, there may be significant environmental issues as well.
Appropriate Measures and Data	Key process measures are the number of intersection quadrants in which sight distance was improved and the amount of increase in sight distance achieved. Where issues of potential effect on adjacent properties exist, a process measure may be used to describe this, such as the number of private properties on which alterations were made. Crash frequency and severity, by type, are key safety effectiveness measures. Separate analysis of crashes targeted by the sight distance improvements is desirable. Crash frequency and severity data are needed. If feasible, both total crashes and crash types targeted by the improvement should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	None identified.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	This strategy should be incorporated in highway design policies and highway maintenance manuals. Nearly any highway agency can participate in implementing this strategy.
Issues Affecting Implementation Time	Projects involving changing the horizontal and/or vertical alignment to provide more sight distance are quite extensive and usually take from 1 to 3 years to accomplish. If additional right-of-way is required, these projects will also involve discussions with adjacent property owners, which may require a substantial period of time.
Costs Involved	Projects involving changing the horizontal and/or vertical alignment are generally high cost, especially if additional right-of-way is required. Potential funding sources include federal, state, or local highway agencies.
Training and Other Personnel Needs	Training concerning removal of sight obstructions near intersections should be included in highway agency training concerning geometric design, highway safety, and highway maintenance.
Legislative Needs	None identified.

EXHIBIT V-27 (Continued)
Strategy Attributes for Changing Horizontal and/or Vertical Alignment of Approaches to Provide More Sight Distance (T)

Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets*, Washington, D.C. (2001).

NCHRP Report 383: Intersection Sight Distance (Harwood, Mason, Brydia, Pietrucha, and Gittings, 1996), Transportation Research Board of the National Academies.

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

Strategy 17.1 C4—Eliminate Parking that Restricts Sight Distance (T)

General Description

Adequate sight distance for drivers at stop-controlled approaches to intersections has long been recognized as among the most important factors contributing to overall intersection safety. Although geometrically an intersection might have adequate sight distance, parking within the sight triangle might restrict it and should, therefore, be taken into consideration. Estimates of the safety effectiveness of eliminating parking that restricts sight distance have not been yet developed. Increased enforcement of existing parking prohibitions may be needed to ensure the successful implementation of this strategy.

EXHIBIT V-28
Strategy Attributes for Eliminating Parking that Restricts Sight Distance (T)

Technical Attributes	
Target	The target for this strategy is unsignalized intersections with restricted sight distance due to parking.
Expected Effectiveness	There is no research that adequately quantifies the effectiveness of improving sight distance at unsignalized intersections due to elimination of parking. A group of safety experts recently reviewed the literature and estimated that if the available sight distance in any quadrant of an intersection is less than or equal to the design sight distance for a speed of 20 km/h less than the actual 85th-percentile speed of the approach, then the frequency of related crashes at the intersection would be increased by 5 percent (Harwood et al., 2000). Thus, a project may be 0 to

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EXHIBIT V-28 (Continued)
Strategy Attributes for Eliminating Parking that Restricts Sight Distance (T)

	20 percent effective in reducing related crashes, depending upon the severity of the existing sight restriction and the number of intersection quadrants affected. ISD-related crashes include angle- and turning-related collisions. Further research to better quantify the safety effectiveness of ISD improvements would be desirable.
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 due to parking. Currently this is a judgment made by an experienced safety analyst. It may often require detailed study of individual crash reports for the intersection, as well as field visits and measurement.
Potential Difficulties	The most difficult aspect of this strategy is the reaction of adjacent property holders and users who may be negatively impacted by the removal of nearby parking spaces. Public compliance with parking restrictions may present a problem.
Appropriate Measures and Data	Key *process measures* are the *number of intersection quadrants in which sight distance was improved by restricting parking* and *the amount of increase in sight distance achieved.* Where issues of potential effect on adjacent properties exist, an impact measure may be used to describe this, such as the number of private properties that will be affected by the elimination of the parking spaces. Furthermore, the effectiveness of the strategy will depend upon compliance of drivers with the parking restrictions that are instituted. Therefore, a secondary measure of compliance is important to use when conducting an evaluation. *Crash frequency and severity, by type,* are key safety effectiveness measures. Separate analysis of crashes targeted by the sight distance improvements is desirable. Crash frequency and severity data are needed. If feasible, both total crashes and crash types targeted by the improvement should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	There will be a need to have enforcement of the parking restrictions, especially in the period immediately following the institution of the new restrictions.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	This strategy should be incorporated in highway design policies and highway maintenance manuals. The involvement of law enforcement agencies with jurisdiction for the intersection will be important. This should be sought at the earliest possible point in the process. Nearly any highway agency can participate in implementing this strategy.
Issues Affecting Implementation Time	Projects involving eliminating parking can typically be accomplished in 3 months or less, assuming that the removal of the parking space is not controversial.
Costs Involved	Costs will generally be low and will include signing and enforcement costs. Some targeted enforcement may be required, but this may usually be accomplished within the normal patrol activities of the agency(ies) within whose jurisdiction the intersection is located.

EXHIBIT V-28 (Continued)
Strategy Attributes for Eliminating Parking that Restricts Sight Distance (T)

Training and Other Personnel Needs	Training concerning removal of parking near intersections should be included in highway agency training concerning geometric design, highway safety, and highway maintenance.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Washington, D.C. (2001).

NCHRP Report 383: Intersection Sight Distance (Harwood, Mason, Brydia, Pietrucha, and Gittings, 1996), Transportation Research Board of the National Academies.

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

Objective 17.1 D—Improve Availability of Gaps in Traffic and Assist Drivers in Judging Gap Sizes at Unsignalized Intersections

Strategy 17.1 D1—Provide an Automated Real-Time System to Inform Drivers of the Suitability of Available Gaps for Making Turning and Crossing Maneuvers (E)

General Description

The lack of adequate sight distance at unsignalized intersections may reduce the ability of drivers to see an approaching vehicle and/or judge the suitable available gap for making turning and crossing maneuvers. Even where sight distance is adequate, drivers may ignore traffic control devices such as stop or yield signs and may misjudge available gaps in traffic. Thus, intersection crashes may occur because drivers are unable to judge adequately the distance to an approaching vehicle. Automated systems can be used to assist drivers in judging the adequacy of available gaps in traffic for entering the major road from a stop- or yield-controlled approach. Such systems can range from simple pavement loop detectors and flashing lights with a simple control algorithm to more complex real-time computer-controlled systems.

A simple system of this type has been implemented by the Missouri DOT (Exhibit V-29). FHWA has been experimenting with a more complex "collision countermeasure system," or CCS (see Appendix 1 and Appendix 2), designed to enhance driver awareness not only of the approaching intersection, but also of real-time traffic conditions (FHWA, 1998). CCS does this by providing warnings of vehicles that are entering the approaching intersection. Drivers approaching an intersection on a major through road will be warned by a flashing car symbol on a dynamic roadside sign that one or more vehicles are about to enter the intersection from the cross street. The system will also warn drivers on the cross road that there is traffic approaching on the through road.

EXHIBIT V-29
Automated Real-Time System to Identify Available Gaps—Missouri DOT

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Federal Highway Administration, *Collision Countermeasure System (CCS)* (Brochure provided by Paul Pisano, 1998).

Evaluation of the Prince William County Collision Countermeasure System, Virginia Transportation Research Council, VTRC 01-CR5, February 2001 (Hanscom).

Intersection Collision Avoidance Using ITS Countermeasures, Task 9 final report, Veridian Engineering Report 8149-12 (Pierowicz et al.), 2000.

Strategy 17.1 D2—Provide Roadside Markers or Pavement Markings to Assist Drivers in Judging the Suitability of Available Gaps for Making Turning and Crossing Maneuvers (E)

General Description

The lack of adequate sight distance at unsignalized intersections may reduce the ability of drivers to see an approaching vehicle and/or judge the suitable available gap for making turning and crossing maneuvers. Even where sight distance is adequate, drivers may ignore traffic control devices such as stop or yield signs and may misjudge available gaps in traffic. Thus, intersection crashes may occur because drivers are unable to judge adequately the distance and time to an approaching vehicle. Strategy 17.1 D1 focused on automated systems to provide real-time information to assist drivers in judging the suitability of available gaps in traffic. Strategy 17.1 D2 involves the use of passive markings at a fixed distance (or fixed travel time) from an intersection to assist drivers in deciding when to accept a gap. The markings could take the form of roadside markers or pavement markings placed in the field of view of a driver observing the approaching traffic stream. Drivers would need to be told, by signing or through a public education campaign, not to proceed when an approaching vehicle is closer to the intersection than the marker is. The Pennsylvania DOT (PENNDOT) is currently testing a system like this, involving painted roadside "goalposts." PENNDOT is also trying a scaled-down version of markings using words such as "SLOW" on the pavement along the approach to an intersection.

This strategy is considered experimental. If an agency desires to pursue its application, it is recommended that the agency proceed with caution, conducting pilot tests in conjunction with a carefully planned evaluation.

Strategy 17.1 D3—Retime Adjacent Signals to Create Gaps at Stop-Controlled Intersections (T)

General Description

Drivers have difficulty making turning maneuvers at some unsignalized intersections because of the lack of sufficiently large gaps in through traffic. The lack of gaps can lead some impatient drivers to accept gaps shorter than needed for safe turning maneuvers, thus leading to turn-related crashes. Such crashes could be minimized if longer gaps could be made available. One method to provide longer gaps is to retime traffic signals at nearby intersections to create more gaps in traffic for turning maneuvers at the unsignalized intersection. The process of retiming signals may also involve rephasing.

EXHIBIT V-30
Strategy Attributes for Retiming of Adjacent Signals to Create Gaps at Stop-Controlled Intersections (T)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections with right-angle or turning-related crash patterns attributable to lack of sufficient gaps in through traffic on the major road for safe turning maneuvers. The strategy is applicable to unsignalized intersections near a signalized intersection at which the signal timing can be modified to create longer gaps.
Expected Effectiveness	The strategy is presumed to be effective in reducing right-angle and turn-related collisions, but its effectiveness has not been quantified. Further research to quantify the effectiveness of this strategy would be desirable.
Key to Success	The key to success is to identify signal timing for operation of the signalized intersection that results in suitable gaps in traffic at downstream unsignalized intersections.
Potential Difficulties	A potential pitfall can occur when signal-timing changes significantly reduce the level of service and/or progression on the through street or elsewhere in the system. Furthermore, the distribution of gaps at other unsignalized intersections may be negatively effected. Care must be taken to check for system effects of a timing change. This pitfall can theoretically extend to conflicts with other programs. For example, arterial and major intersection signal-timing projects are often justified by, and funded through, special congestion mitigation and air-quality improvement programs. Suggestions to alter the signal timing in a corridor to achieve safety improvements could result in unintended consequences to previous engineering decisions focusing on other issues.
Appropriate Measures and Data	A key process measure is the number of intersection approaches at which signal timing is altered for this purpose. Crash frequency and severity, by type, are key safety effectiveness measures. Separate analysis of crashes targeted by the improvement is desirable. An important surrogate or companion impact measure is the distribution of headways past the subject unsignalized intersections. Crash frequency and severity data are needed. If feasible, both total crashes and crashes related to targeted turning movements at the intersection should be analyzed separately. Traffic volume and gap-distribution data are needed to represent exposure and measure the basic problem, respectively.
Associated Needs	None identified.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	This strategy often requires close cooperation among multiple agencies. In many cases, particularly in urban and suburban areas, the through roadway and signalization is the responsibility of one agency (e.g., a state highway agency), and the intersecting roadway is the responsibility of a local community. No specific changes in highway agency policies are needed to implement this strategy. Any highway agency that operates signalized and unsignalized intersections on urban and suburban arterials can participate in implementing this strategy.

EXHIBIT V-30 (Continued)
Strategy Attributes for Retiming of Adjacent Signals to Create Gaps at Stop-Controlled Intersections (T)

Issues Affecting Implementation Time	This strategy requires only changes to signal timing or hardware, so it can be implemented very quickly. The strategy can be implemented in 1 month or less if only reprogramming of signal hardware is required. Where signal hardware must be upgraded to implement this strategy, a lead time of 6 months to 1 year is needed.
Costs Involved	Unless new hardware is required, costs to retime signals are nominal; the greatest costs will be associated with conducting the necessary traffic field studies to verify the problem and develop an effective solution.
Training and Other Personnel Needs	The use of this technique should be addressed in training on geometric design and safety improvement on urban and suburban arterials. Procedures for retiming signals appropriately should be addressed in training on traffic signal control.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	The strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections. This strategy may be an alternative to closing or restricting turning movements associated with existing accident patterns.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

Objective 17.1 E—Improve Driver Awareness of Intersections as Viewed from the Intersection Approach

Strategy 17.1 E1—Improve Visibility of Intersections by Providing Enhanced Signing and Delineation (T)

General Description

Many unsignalized intersections are not readily visible to approaching drivers, particularly drivers on major-road approaches that are not controlled by stop or yield signs. Thus, intersection crashes may occur because approaching drivers may be unaware of the presence of the intersection. The visibility of intersections and, thus, the ability of approaching drivers to perceive them can be enhanced by signing and delineation (see Exhibit V-31). Improvements may include advance guide signs, advance street name signs, warning signs, pavement markings, and post-mounted delineators.

The FHWA *Older Driver Highway Design Handbook* (Staplin et al., 1998) encourages such improvements to contribute to a better driving environment for older drivers. In particular, the handbook addresses advance guide signs and letter height on guide signs as key issues for older drivers. Advance warning signs, such as the standard intersection warning sign, can also alert drivers to the presence of an intersection. Providing a break in pavement markings—including centerlines, lane lines, and edge lines—at intersections also helps to alert drivers to the presence of an intersection.

EXHIBIT V-31
Examples of High-Visibility Signing

EXHIBIT V-32
Strategy Attributes for Improving Visibility of Intersections by Providing Enhanced Signing and Delineation (T)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections that are not clearly visible to approaching motorists, particularly approaching motorists on the major road. The strategy is particularly appropriate for intersections with patterns of rear-end, right-angle, or turning collisions related to lack of driver awareness of the presence of the intersection.

EXHIBIT V-32 (Continued)
Strategy Attributes for Improving Visibility of Intersections by Providing Enhanced Signing and Delineation (T)

Expected Effectiveness	Making drivers aware that they are approaching an intersection, through the use of enhanced signing and delineation, should improve safety at the intersection because drivers will be more alert to potential vehicles on the cross streets. This heightened awareness will quicken drivers' reaction times when conflicts occur. However, the effectiveness of this strategy has not been quantified.
Key to Success	A key to success in applying this strategy is to select a combination of signing and delineation techniques appropriate to conditions on particular unsignalized intersection approaches. This engineering assessment should, where possible, be accompanied by a human-factors assessment of signing and delineation needs. Another key to success is the ability and commitment of the highway agency to adequately maintain the signing or delineation.
Potential Difficulties	Care should be taken not to overuse traffic signing, which would result in drivers not perceiving the presence of intersections.
Appropriate Measures and Data	A key process measure is the number of intersection approaches on which advanced warning of the intersection was improved or visual cues to the presence of the intersection were provided. Crash frequency and severity, by type, are key safety effectiveness measures. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	There are no public information and education needs in connection with the implementation of this strategy because most drivers are familiar with the traffic control devices used.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Nearly any highway agency can participate in the implementation of this strategy, which is applicable to unsignalized intersections in rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy does not require a long development process. Signing and delineation improvements can typically be implemented in 3 months or less.
Costs Involved	Costs to implement signing and delineation are relatively low. An agency's maintenance costs may increase. Potential funding sources for this strategy include state and local highway agencies.
Training and Other Personnel Needs	Training regarding use of this strategy should be provided in highway agency courses covering the use of traffic control devices.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

FHWA-RD-97-135, *Older Driver Highway Design Handbook* (Staplin, Lococo, and Byington, 1998).

Strategy 17.1 E2—Improve Visibility of the Intersection by Providing Lighting (P)

General Description

Providing lighting at the intersection itself, or both at the intersection and on its approaches, can make drivers aware of the presence of the intersection and reduce nighttime crashes.

EXHIBIT V-33
Strategy Attributes for Improving Visibility of the Intersection by Providing Lighting (P)

Technical Attributes	
Target	The target for this strategy should be unsignalized, unlit intersections with substantial patterns of nighttime crashes. In particular, patterns of rear-end, right-angle, or turning collisions on the major-road approaches to an unsignalized intersection may indicate that approaching drivers are unaware of the presence of the intersection.
Expected Effectiveness	Minnesota evaluated the effectiveness of installing streetlights at rural intersections. As part of the evaluation, Minnesota conducted a literature review and found that previously published research reported 25 to 50 percent reductions in the nighttime crash/total crash ratio due to the installation of intersection lighting (Preston and Schoenecker, 1999b). Based upon a comparative crash analysis and a before-after evaluation, Minnesota concluded that the installation of streetlights reduced nighttime accidents at rural intersections and would be more effective in reducing nighttime crashes than either rumble strips or overhead flashing beacons. From an economic standpoint, Minnesota indicated that the benefits associated with the installation of streetlights at rural intersections outweigh the costs by a margin of 15 to 1. Based upon the Minnesota study and previous studies, providing lighting at an intersection improves the safety of an intersection during nighttime conditions by (1) making drivers more aware of the intersection, which improves drivers' perception-reaction times, (2) enhancing drivers' available sight distances, and (3) improving the visibility of nonmotorists.
Key to Success	The keys to the success of this strategy are (1) identifying sites where a lack of lighting is truly a significant factor in the nighttime crash experience and (2) developing an appropriate lighting system following AASHTO and the Illuminating Engineering Society of North America (IESNA) criteria.
Potential Difficulties	Lighting is feasible only where an appropriate supply of electrical power is available. This is not usually a problem in urban and suburban areas, but some rural intersections where lighting would be desirable may be isolated from power sources.
Appropriate Measures and Data	The key process measure is the number of intersections where lighting was improved. Nighttime crash frequency and severity, by type, are key safety effectiveness measures. The ratio of nighttime to daytime crashes, by type, is also a useful measure for determining safety effectiveness.

EXHIBIT V-33 (Continued)
Strategy Attributes for Improving Visibility of the Intersection by Providing Lighting (P)

	Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	None identified.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that their policies have appropriate guidelines for lighting of intersections. Nearly any highway agency can participate in the implementation of this strategy, including agencies that administer highway systems in rural, urban, and suburban areas.
Issues Affecting Implementation Time	A lighting project generally requires at least 1 year to implement because the lighting system must be designed and because the provision of electrical power must be arranged.
Costs Involved	The provision of lighting involves both fixed cost for lighting installation and an ongoing maintenance and power cost.
Training and Other Personnel Needs	Training on the effective use of lighting should be provided for highway agency personnel.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections. In particular, this strategy may be compatible with Strategy 17.1 E11, Install Flashing Beacons, a strategy that also requires an electrical power source.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

MN/RC-1999-17, *Safety Impacts of Street Lighting at Isolated Rural Intersections* (Preston and Schoenecker, 1999b).

FHWA-TS-80-223, *New Directions in Roadway Lighting* (Gallagher, 1980).

FHWA-RD-96-125, *Statistical Models of At-Grade Intersection Accidents* (Bauer and Harwood, 1996).

Transportation Research Record 1247, "Major Road Accident Reduction by Illumination" (Box, 1988), Transportation Research Board of the National Academies.

City of Los Angeles, Bureau of Street Lighting, OTS Project 127803, *Intersection Accident Reduction through Street Lighting* (1980).

Strategy 17.1 E3—Install Splitter Islands on the Minor-Road Approach to an Intersection (T)

General Description

Many unsignalized intersections are not visible to approaching drivers. Thus, intersection crashes may occur because one or more drivers may be unaware of the intersection. "Splitter" islands can be installed on minor-road approaches to call attention to the presence of the intersection and to guide traffic through the intersection. A splitter island refers to a channelizing island that separates traffic in opposing directions of travel, as opposed to islands that separate merging or diverging traffic in the same direction of travel. Splitter islands are particularly appropriate on approaches to skewed intersections.

EXHIBIT V-34
Strategy Attributes for Installing Splitter Islands on the Minor-Road Approaches to an Intersection (T)

Technical Attributes	
Target	The target for this strategy should be minor-road approaches to unsignalized intersections on which the presence of the intersection or the stop sign is not readily visible to approaching motorists. The strategy is particularly appropriate for intersections where the speeds on the minor road are high.
Expected Effectiveness	Splitter islands are generally perceived to be effective in defining the presence of an intersection. When properly applied, they may reduce traffic speeds and intersection crashes, but there is no consensus on their effectiveness. Further research to quantify the safety effectiveness of splitter islands is desirable.
Key to Success	A key to success in applying this strategy is designing the island in accordance with the principles of channelization presented in the AASHTO *Policy on Geometric Design of Highways and Streets* and *NCHRP Report 279: Intersection Channelization Design Guide* (Neuman, 1985). The visibility of the splitter island will in part depend on its placement relative to the profile of the major road.
Potential Difficulties	There is a potential for the safety effectiveness of splitter islands to be negated if the shoulder is used in place of widening of the roadbed to accomplish the channelization.
Appropriate Measures and Data	*A key process measure is the number of intersection approaches on which splitter islands were installed on minor-road approaches.* *Crash frequency and severity, by type,* are key safety effectiveness measures. Total crashes and crash types potentially affected by the use of splitter islands should be analyzed separately. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	Drivers understand splitter islands with no need for special public education campaigns. However, public information should be distributed about any forthcoming change in traffic control.

EXHIBIT V-34 (Continued)
Strategy Attributes for Installing Splitter Islands on the Minor-Road Approaches to an Intersection (T)

Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agency geometric design policies should incorporate appropriate uses of splitter islands. Nearly any highway agency can participate in the implementation of this strategy. While the strategy is applicable to both rural and urban locations, the greatest need is for agencies that operate extensive systems of urban and suburban arterials.
Issues Affecting Implementation Time	Intersection improvements involving splitter islands generally take approximately 1 to 2 years to design and construct. Significant channelization may require minor right-of-way acquisition, which could further increase implementation time.
Costs Involved	Costs involved in implementing splitter islands are moderate, unless acquisition of additional right-of-way is required, in which case costs may be higher.
Training and Other Personnel Needs	Appropriate use of splitter islands should be addressed in geometric design training courses.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

NCHRP Report 279: Intersection Channelization Design Guide (Neuman, 1985), Transportation Research Board of the National Academies.

Strategy 17.1 E4—Provide a Stop Bar (or Provide a Wider Stop Bar) on Minor-Road Approaches (T)

General Description

Providing visible stop bars on minor-road approaches to unsignalized intersections can help direct the attention of drivers to the presence of the intersection. Where a stop bar is already in place, provision of a wider stop bar may be considered.

EXHIBIT V-35
Strategy Attributes for Providing a Stop Bar (or Providing a Wider Stop Bar) on Minor-Road Approaches (T)

Technical Attributes	
Target	The target for this strategy should be approaches to unsignalized intersections having traffic control devices that are not currently being recognized by some approaching motorists. Locations should be identified by patterns of crashes related to lack of driver recognition of the traffic control device (e.g., right-angle collisions related to stop sign violations).
Expected Effectiveness	The effectiveness of this strategy in reducing crashes has not been satisfactorily quantified. Further research to quantify the safety effectiveness of this strategy would be desirable.
Key to Success	A key to the success of this strategy is identifying appropriate intersection approaches that would benefit from its use. The strategy is expected to be especially effective when applied on approaches where conditions allow the stop bar to be seen by an approaching driver at a significant distance from the intersection. This strategy is appropriate for locations with a pattern of angle collisions associated with stop sign violations where approaching drivers may not realize that an intersection is present until it is too late to stop.
Potential Difficulties	None identified.
Appropriate Measures and Data	A key process measure is the number of intersection approaches where a stop bar (or wider stop bar) is installed. Crash frequency and severity data, by type, represent key safety effectiveness measures. Both total crashes and crash types potentially affected by the use of a stop bar (or wider stop bar) should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	Drivers understand stop bars on minor-road approaches with no need for special public education campaigns.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Use of stop bars should be addressed in highway agency policies and manuals concerning traffic control devices. Nearly any highway agency can participate in the implementation of this strategy, which is applicable in rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy can be implemented quickly, typically in less than 3 months.
Costs Involved	Costs for implementing this strategy are nominal. An agency’s maintenance costs may increase.
Training and Other Personnel Needs	Appropriate use of stop bars should be addressed in highway agency training courses concerning traffic control devices.
Legislative Needs	None identified.

EXHIBIT V-35 (Continued)
Strategy Attributes for Providing a Stop Bar (or Providing a Wider Stop Bar) on Minor-Road Approaches (T)

Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

Strategy 17.1 E5—Install Larger Regulatory and Warning Signs at Intersections (T)

General Description

The visibility of intersections and, thus, the ability of approaching drivers to perceive them can be enhanced by installing larger regulatory and warning signs at intersections. Such improvements may include advance guide signs, warning signs, pavement markings, and post-mounted delineators. The FHWA *Older Driver Highway Design Handbook* (Staplin et al., 1998) encourages such improvements to contribute to a better driving environment for older drivers.

EXHIBIT V-36
Strategy Attributes for Installing Larger Regulatory and Warning Signs at Intersections (T)

Technical Attributes	
Target	The target for this strategy should be approaches to unsignalized intersections with patterns of rear-end, right-angle, or turning collisions related to lack of driver awareness of the presence of the intersection.
Expected Effectiveness	The effectiveness of this strategy in reducing crashes has not been satisfactorily quantified. Further research to develop safety effectiveness measures for this strategy is desirable.
Key to Success	A key to success in applying this strategy is to select a combination of regulatory and warning sign techniques appropriate to conditions on particular unsignalized intersection approaches. This engineering judgment should, where possible, be accompanied by a human factors assessment of the need for regulatory and warning signs. Another key to success is the ability and commitment of the highway agency to adequately maintain the signs.

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EXHIBIT V-36 (Continued)
Strategy Attributes for Installing Larger Regulatory and Warning Signs at Intersections (T)

Potential Difficulties	Care should be taken not to overuse traffic signing, as it is likely that drivers will become accustomed to their presence and fail to respond as desired or intended. Agencies should strive to use special signing only where a specific problem or circumstance indicates the need.
Appropriate Measures and Data	A key process measure is the number of intersection approaches where larger signs are used. Crash frequency and severity, by type, are key safety effectiveness measures. Crash frequency and severity data are needed. Both total crashes and crash types potentially affected by the use of larger regulatory and warning signs should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	Drivers understand regulatory and warning signs at intersections with no need for special public education campaigns.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Nearly any highway agency can participate in the implementation of this strategy, which is applicable to unsignalized intersections in rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy does not require a long development process. Signing improvements can typically be implemented in 3 months or less.
Costs Involved	Costs for implementing this strategy are nominal. An agency's maintenance costs may increase.
Training and Other Personnel Needs	Training regarding use of this strategy should be provided in highway agency training courses concerning the use of traffic control devices.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

FHWA-RD-97-135, *Older Driver Highway Design Handbook* (Staplin, Lococo, and Byington, 1998).

Strategy 17.1 E6—Call Attention to the Intersection by Installing Rumble Strips on Intersection Approaches (T)

General Description

Rumble strips can be installed on intersection approaches to call attention to the presence of the intersection and to the traffic control in use at the intersection. Rumble strips are particularly appropriate on stop-controlled approaches to intersections where a pattern of crashes is present related to lack of driver recognition of the presence of the stop sign. Rumble strips should be used sparingly. Their effectiveness is dependent on being unusual. Rumble strips are normally applied when less intrusive measures—such as pavement markings like "STOP AHEAD" signs, markings, or flashers—have been tried and have failed to correct the crash pattern. Rumble strips can be used to supplement such traffic control devices. For example, a rumble strip can be located so that when the driver crosses the rumble strip, a key traffic control device such as a "STOP AHEAD" sign is directly in view. Rumble strips in the traveled way can also be used on a temporary basis to call attention to changes in traffic control devices, such as installation of a stop sign where none was present before. *NCHRP Synthesis of Highway Practice 191* (Harwood, 1993) reviews the state of the art of rumble strip usage.

EXHIBIT V-37
Strategy Attributes for Installing Rumble Strips on Intersection Approaches (T)

Technical Attributes	
Target	The target for this strategy should be approaches to unsignalized intersections with traffic control devices that are not currently being recognized by some approaching motorists. Locations should be identified by patterns of crashes related to lack of driver recognition of the traffic control device (e.g., right-angle collisions related to stop sign violations). Rumble strips should be considered only after adequate trial of less intrusive treatments.
Expected Effectiveness	Rumble strips are generally perceived to be effective in reducing intersection crashes when used appropriately, but there is no consensus on their effectiveness. A review of literature suggests that rumble strips on intersection approaches can provide a reduction of at least 50 percent in the types of crashes most susceptible to correction by rumble strips, including rear-end collisions and crashes involving running through a stop sign (Harwood, 1993).
Key to Success	A key to success in implementing rumble strips is to use them sparingly so that they retain their surprise value in gaining the driver's attention.
Potential Difficulties	Rumble strips in the traveled way have several potential pitfalls that should be considered carefully in any decision to implement them. They include (1) noise that may disturb nearby residents; (2) potential loss-of-control problems for motorcyclists and bicyclists; (3) difficulties created for snowplow operations; and (4) inappropriate driver responses such as using the opposing travel lanes to drive around the rumble strip.
Appropriate Measures and Data	A key process measure is the number of intersection approaches on which rumble strips are installed.

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EXHIBIT V-37 (Continued)
Strategy Attributes for Installing Rumble Strips on Intersection Approaches (T)

	Crash frequency and severity, by type, are key safety effectiveness measures. If feasible, both total crashes and crash types potentially affected by the use of rumble strips should be analyzed separately. In some cases, measures of noise resulting from the rumble strips may need to be used to determine impact at nearby residences or other buildings. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	Where traveled-way rumble strips are used for the first time in a particular geographical area, they should be accompanied by appropriate pubic information and education.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agency traffic control policies should incorporate appropriate uses of rumble strips. Nearly any highway agency can participate in the implementation of this strategy. While the strategies are applicable to both rural and urban locations, rumble strips are most appropriate in rural locations due to noise considerations near urban residences.
Issues Affecting Implementation Time	Rumble strips typically can be implemented in 3 months or less.
Costs Involved	Costs to implement rumble strips would normally be nominal.
Training and Other Personnel Needs	Training concerning design and construction of rumble strips should be provided for highway agency personnel.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections that are to remain in place. The strategy would not be compatible with strategies involving removal or relocation of the intersection.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

NCHRP Synthesis of Highway Practice 191: Use of Rumble Strips to Enhance Safety (Harwood, 1993), Transportation Research Board of the National Academies.

Highway Research Board of the National Academies, Proceedings, Volume 41, *Effect of Rumble Strips on Traffic Control and Behavior* (Kermit and Hein, 1962).

Highway Research Record 170, "Effect of Rumble Strip at Rural Stop Locations on Traffic Operation" (Owens, 1967), Highway Research Board of the National Academies.

Illinois Division of Highways, *Accident Study Report 102: Rumbles Strips Used as a Traffic Control Device: An Engineering Analysis* (1970).

TRRL Laboratory Report 800, *The Use of Rumble Areas to Alert Drivers* (Sumner and Shippey, 1977), Transport and Road Research Laboratory, Department of Environment, Department of Transport, Crowthorne, Berkshire, United Kingdom.

Virginia Department of Highways and Transportation, *An Evaluation of the Effectiveness of Rumble Strips* (1991).

HR-235, *Warrants for Rumble Strips on Rural Highways* (Carstens and Woo, 1982), Iowa Highway Research Board.

Transportation Research Record 1069, "Rumble Strips and Paint Stripes at a Rural Intersection" (Zaidel, Hakkert, and Barkan, 1986), Transportation Research Board of the National Academies.

FHWA-LA-86-186, *Evaluation of Experimental Rumble Strips* (Moore, 1987), Louisiana Transportation Research Center.

M.S. Thesis, Pennsylvania State University, *Grooved Rumble Strips as a Traffic Control Device in Pennsylvania* (Taylor, 1974).

UKTRP-81-11, *Evaluation of Rumble Strip Design and Usage* (Pigman and Barclay, 1981), Kentucky Transportation Research Program.

Strategy 17.1 E7—Provide Dashed Markings (Extended Left Edgelines) for Major-Road Continuity Across the Median Opening at Divided Highway Intersections (T)

General Description

Providing dashed markings (extended left edgelines) to define median roadway area at divided highway intersections can help distinguish the median roadway from the through roadway and, thus, enhance the ability of approaching drivers to be more aware of the presence of the intersection.

EXHIBIT V-38
Strategy Attributes for Providing Dashed Markings (Extended Left Edgelines) for Major-Road Continuity Across the Median Opening at Divided Highway Intersections (T)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections on divided highways. The strategy is particularly appropriate for intersections with patterns of rear-end, right-angle, or turning collisions related to lack of driver awareness of the presence of the intersection. This strategy should assist in reducing collisions between vehicles using the median roadway and through traffic. Extended edgelines, for example, should make it less likely for drivers of vehicles in the median roadway to stop in a position with a portion of their vehicle encroaching on the through roadway.
Expected Effectiveness	The effectiveness of this strategy in reducing crashes has not been satisfactorily quantified.

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EXHIBIT V-38 (Continued)
Strategy Attributes for Providing Dashed Markings (Extended Left Edgelines) for Major-Road Continuity Across the Median Opening at Divided Highway Intersections (T)

	Further research to quantify the safety effectiveness of this strategy would be desirable.
Key to Success	A key to success in applying this strategy is to select a combination of marking techniques appropriate to conditions on particular unsignalized intersection approaches on divided highways. This engineering judgment should, where possible, be accompanied by a human-factors assessment of marking needs. Another key to success is the ability and commitment of the highway agency to maintain the markings adequately.
Potential Difficulties	None identified.
Appropriate Measures and Data	A key process measure is the number of intersections where markings are improved. Crash frequency and severity, by type, are key safety effectiveness measures. Crash frequency and severity data are needed. If feasible, both total crashes and crash types potentially affected by the use of dashed markings to define the median roadway area should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	Although the dashed marking is not presented in the MUTCD, drivers should understand this marking to define the median roadway area at divided intersections with no need for special public education campaigns.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Nearly any highway agency can participate in the implementation of this strategy, which is applicable to unsignalized intersections in rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy does not require a long development process and can typically be implemented in 3 months or less.
Costs Involved	Costs to implement this strategy are nominal. An agency’s maintenance costs may increase.
Training and Other Personnel Needs	Training regarding use of this strategy should be provided in highway agency courses concerning the use of traffic control devices.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

Strategy 17.1 E8—Provide Supplementary Stop Signs Mounted Over the Roadway (T)

General Description

Many stop signs at stop-controlled intersections are not readily visible to approaching drivers due to geometric conditions, presence of vegetation, or other objects (such as tall vehicles) that can limit the view of the regular stop signs. Thus, intersection crashes may occur because approaching drivers may be unaware of the presence of the stop sign at the intersection. The visibility of stop signs and, thus, the ability of approaching drivers to perceive them can be enhanced by providing supplementary stop signs suspended over the roadway.

The target for this strategy should be stop signs at intersections that are not clearly visible to approaching motorists, particularly approaching motorists on the minor road. The strategy is particularly appropriate for intersections with patterns of rear-end, right-angle, or turning collisions related to lack of driver awareness of the presence of the intersection or stop sign.

EXHIBIT V-39
Strategy Attributes for Providing Supplementary Stop Signs Mounted Over the Roadway (T)

Technical Attributes	
Target	This strategy is appropriate for unsignalized intersections with patterns of right-angle collisions related to lack of driver awareness of the presence of the intersection. In particular, it might be appropriate to use this strategy at the first stop-controlled approach (possibly of a series) located on a long stretch of highway without any required stops, or at an intersection located after a sharp horizontal curve.
Expected Effectiveness	The safety effectiveness of providing supplementary stop signs mounted over the roadway has not been quantified. Research to quantify the safety effectiveness of this strategy would be desirable.
Key to Success	The key to success is to locate the supplementary overhead sign (or signs) in the direct line of sight of approaching drivers.
Potential Difficulties	Unless the signs are mounted on existing overhead structures (mast arms), additional hardware will have to be placed on the roadside, which could become an additional object that a vehicle may strike if it leaves the roadway.
Appropriate Measures and Data	A key process measure is the number of intersections where supplementary stop signs are provided overhead. Crash frequency and severity, by type, are key safety effectiveness measures.

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EXHIBIT V-39 (Continued)
Strategy Attributes for Providing Supplementary Stop Signs Mounted Over the Roadway (T)

	Crash frequency and severity data are needed. If feasible, both total crashes and crash types potentially affected by the supplementary signs (e.g., right-angle) should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	Supplementary signs should be in accordance with MUTCD guidelines.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Nearly any highway agency can participate in the implementation of this strategy.
Issues Affecting Implementation Time	This strategy does not require a long development process and can typically be implemented in 3 months or less.
Costs Involved	The costs involved in providing supplementary overhead stop signs are minimal when the signs are mounted on existing structures. The additional cost of providing a mast arm is moderate. Agencies may experience additional maintenance costs.
Training and Other Personnel Needs	Training regarding use of this strategy should be provided in highway agency courses concerning the use of traffic control devices.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

Strategy 17.1 E9—Provide Pavement Markings with Supplementary Messages, Such as STOP AHEAD (T)

General Description

Providing pavement markings with supplementary messages (such as STOP AHEAD) can help alert drivers and thus enhance the ability of approaching drivers to be more aware of the presence of the intersection. These marking should follow MUTCD guidelines.

EXHIBIT V-40
Strategy Attributes for Providing Pavement Markings with Supplementary Messages, Such as STOP AHEAD (T)

Technical Attributes	
Target	This strategy is particularly appropriate for unsignalized intersections with patterns of rear-end, right-angle, or turning collisions related to lack of driver awareness of the presence of the intersection.
Expected Effectiveness	Several studies have been done to determine the effectiveness of STOP AHEAD signs as prescribed by MUTCD, but the effectiveness of providing pavement markings with supplementary messages in reducing crashes has not been satisfactorily quantified. Further research to quantify the safety effectiveness of this strategy would be desirable.
Key to Success	A key to success in applying this strategy is to select a combination of marking techniques appropriate to conditions on particular unsignalized intersection approaches. Another key to success is the ability and commitment of the highway agency to maintain the markings adequately.
Potential Difficulties	Potential difficulties may be encountered in the winter, when these markings may not be as visible to the driver. The pavement markings may also have a lower coefficient of friction compared with the rest of the approach, especially during wet conditions.
Appropriate Measures and Data	A key process measure is the number of intersections where pavement markings with supplementary messages are provided. Crash frequency and severity, by type, are key safety effectiveness measures. Crash frequency and severity data are needed. If feasible, both total crashes and crash types potentially affected by the pavement markings with supplementary messages should be analyzed separately. Traffic volume data are needed to represent exposure.
Associated Needs	Supplementary pavement markings should follow MUTCD guidelines, which drivers should understand with no need for special public education campaigns.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Nearly any highway agency can participate in the implementation of this strategy, which is applicable to unsignalized intersections in rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy does not require a long development process and can typically be implemented in 3 months or less.
Costs Involved	Costs to implement this strategy are nominal. An agency's maintenance costs may increase.
Training and Other Personnel Needs	Training regarding use of this strategy should be provided in highway agency courses concerning the use of traffic control devices.
Legislative Needs	None identified.

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EXHIBIT V-40 (Continued)
Strategy Attributes for Providing Pavement Markings with Supplementary Messages, Such as STOP AHEAD (T)

Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

Strategy 17.1 E10—Provide Improved Maintenance of Stop Signs (T)

General Description

Maintenance of stop signs must be at a high standard to ensure that the effectiveness of the signs is retained. According to MUTCD criteria, stop signs must be kept in proper position, clean, and legible at all times (both by day and by night). Damaged signs should be replaced without undue delay. To ensure adequate maintenance, a suitable schedule for inspection, cleaning, and replacement of stop signs should be established. Employees of highway agencies, police, and other governmental employees whose duties require that they travel on the highways should be encouraged to report any damaged or obscured signs at the first opportunity. Special attention and necessary action should be taken to see that trees, shrubbery, and construction materials do not obscure stop signs and that the stop signs present proper reflectorization.

EXHIBIT V-41
Strategy Attributes for Providing Improved Maintenance of Stop Signs (T)

Technical Attributes	
Target	The target for this strategy should be all stop-controlled intersections.
Expected Effectiveness	The effectiveness of this strategy has not been satisfactorily quantified. Further research to quantify the safety effectiveness of this strategy would be desirable.
Key to Success	A key to success in applying this strategy is to determine an effective maintenance schedule that may be adequately sustained by highway agencies.
Potential Difficulties	None identified.
Appropriate Measures and Data	A key process measure is the number of intersection approaches on which improved maintenance of stop signs have been provided. Another measure would be the existence of an adequate maintenance schedule.

EXHIBIT V-41 (Continued)
Strategy Attributes for Providing Improved Maintenance of Stop Signs (T)

	Crash frequency and severity, by type, are key safety effectiveness measures.
	Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	There are no public information and education needs in connection with the implementation of this strategy.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Nearly any highway agency can participate in the implementation of this strategy, which is applicable to stop-controlled intersections in rural, urban, and suburban areas.
Issues Affecting Implementation Time	This strategy does not require a long development process. A maintenance schedule can typically be developed in 3 months or less.
Costs Involved	Costs for maintenance of stop signs are relatively low. An agency's maintenance costs may increase.
Training and Other Personnel Needs	Training regarding use of this strategy should be provided in highway agency courses covering the use of traffic control devices and maintenance practices.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

FHWA-RD-97-135, *Older Driver Highway Design Handbook* (Staplin, Lococo, and Byington, 1998).

Strategy 17.1 E11—Install Flashing Beacons at Stop-Controlled Intersections (T)

General Description

Overhead flashing beacons can be used at stop-controlled intersections to supplement and call driver attention to stop signs. Flashing beacons are intended to reinforce driver awareness of the stop sign and to help mitigate patterns of right-angle crashes related to stop sign violations. At two-way stop-controlled intersections, flashing beacons are used with red flashers facing the stop-controlled approaches and yellow flashers facing the unstopped approaches. At all-way stop-controlled intersections, red flashers face all approaches. Use of overhead flashing beacons can increase the visibility of intersections for approaching drivers, thus supplementing the signing and delineation improvements discussed in Strategy 17.1 E1. Flashing beacons can also be used on intersection approaches to supplement and call attention to stop signs or STOP AHEAD signs.

EXHIBIT V-42
Strategy Attributes for Installing Flashing Beacons at Stop-Controlled Intersections (T)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections with patterns of right-angle crashes related to lack of driver awareness of the intersection on an uncontrolled approach and lack of driver awareness of the stop sign on a stop-controlled approach.
Expected Effectiveness	Several studies have evaluated the safety effectiveness of flashing beacons at stop-controlled intersections. Ohio compared the safety at rural, low-volume intersections controlled by stop signs and controlled by flashing beacons in conjunction with stop signs (Pant et al., 1992). Ohio found that flashing beacons generally reduced vehicular speeds on the major road, particularly at intersections with sight distance restrictions, but the flashing beacons were not necessarily effective in reducing stop sign violations or accidents. Similarly, California found that overhead yellow-red flashing beacons did not significantly reduce the number of fatal crashes at stop-controlled intersections (Hammer and Tye, 1987). Therefore, additional research may be desirable to further evaluate the safety effectiveness of this strategy.
Key to Success	A key to success in using flashing beacons to reduce crashes is to select intersections with crash patterns appropriate to mitigation by flashing beacons. Otherwise, the use of a flashing beacon may provide no safety benefit. Crash types mitigated by flashing beacons may include right-angle, rear-end, and turning collisions.
Potential Difficulties	If the flashing beacons are not properly placed where they are clearly visible to approaching drivers, they may not be effective. Flashing beacons also should not be overused. Their effectiveness is attributed in part to their relative uniqueness (i.e., they are not typically found at every stop-controlled intersection). Some agencies have reported crashes at red/amber flashers where a driver facing a red flasher assumed that the intersecting approach also had a red flasher. Flashing beacons require an electric power source, which may not be readily available at every rural intersection.
Appropriate Measures and Data	A key process measure is the number of intersections where flashers are installed. Crash frequency and severity, by type, are key safety effectiveness measures. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	Flashing beacons are generally well understood by drivers. At times minor street drivers may be confused regarding the nature of control on the major street. Driver training or public information programs should address this issue.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agency policies concerning traffic control devices should address flashing beacons.

EXHIBIT V-42 (Continued)
Strategy Attributes for Installing Flashing Beacons at Stop-Controlled Intersections (T)

	Nearly any highway agency can participate in the implementation of this strategy, which is applicable in both rural and urban areas.
Issues Affecting Implementation Time	Use of flashing beacons does not require extensive development; flashing beacons can be installed within 3 to 6 months. The major implementation problem is providing power to the site.
Costs Involved	Costs of installing flashing beacons are generally nominal, with the greatest cost being the provision of power to the site.
Training and Other Personnel Needs	Flashing beacons should be addressed in highway agency training concerning traffic control devices.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

FHWA/OH-93/006, *Development of Guidelines for Installation of Intersection Control Beacons* (Pant, Park, and Neti, 1992).

FHWA/CA/TE-87/01, *Overhead Yellow-Red Flashing Beacons* (Hammer and Tye, 1987).

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

Objective 17.1 F—Choose Appropriate Intersection Traffic Control to Minimize Crash Frequency and Severity

Strategy 17.1 F1—Avoid Signalizing Through Roads (T)

General Description

Signalization of unsignalized intersections often leads to an increased frequency of crashes on major roadways. Signals associated with new developments introduce congestion and increase crashes on through roadways that previously operated relatively safely and smoothly. Thus, the key to crash reduction is to avoid installing signal control whenever possible. Alternatives to signal control include all-way stop control; roundabouts; turn prohibitions (e.g., limiting movements to right-turn in and right-turn out); indirect left-turn movements (e.g., jug handles, loops, and median crossovers); and provision of flyovers and other grade separations.

EXHIBIT V-43
Strategy Attributes for Avoiding Signalizing Through Roads (T)

Technical Attributes	
Target	The target for this strategy should be medium- to high-volume unsignalized intersections where installation of signals is being considered. Before a decision to install a signal is made, adequate consideration should be given to less restrictive forms of traffic control.
Expected Effectiveness	The strategies that can be used as alternatives to signals are known to be effective, but their safety effects are highly site specific. It is known that traffic signals generally increase crash frequency when installed. However, there are no established quantitative measures of the effects of traffic signals in increasing crashes or the effects of the alternative strategies in mitigating those effects. The effect of these strategies on crash severity distributions also has not been quantified. Some of the alternative strategies (e.g., indirect left turns) have been used by some highway agencies for many years, but there is no consensus on the strategies' quantitative safety effects. Other strategies (e.g., roundabouts) have only recently come into widespread use. Further research to quantify the safety effectiveness of these techniques is desirable.
Key to Success	A key to success for this strategy is identifying an appropriate alternative design or traffic control method that will operate more safely than a signalized intersection. Some intersections serve traffic volumes that are so high that signalization cannot be avoided.
Potential Difficulties	A potential difficulty with this strategy is that the selected intersection control strategy may operate less efficiently than a signal (i.e., may involve more delay to motorists or produce out-of-direction travel), or the costs and feasibility of alternatives to signals are much greater. The project development process should include an explicit review of the traffic operational performance of the alternatives considered. Care should be taken in implementing intersection control treatments where pedestrians and bicyclists are expected. In such cases, roundabouts should be avoided.
Appropriate Measures and Data	A key process measure is the number of intersections where alternative controls or treatments are installed. Crash frequency and severity, by type, are key safety effectiveness measures. Both total crashes and those crash types potentially affected by the particular traffic control or treatment change should be analyzed separately, where appropriate. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	There is a potential need for public information and education about the strategies selected, particularly when unfamiliar techniques such as roundabouts are used in an area for the first time.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	If not already in place, a set of warrants and guidelines for the alternative controls or treatments should be developed as part of the agency's policies. For example, warrants and guidelines may be needed for determining the appropriate conditions under which roundabouts are to be used in rural areas.

EXHIBIT V-43 (Continued)
Strategy Attributes for Avoiding Signalizing Through Roads (T)

	Some highway agencies have adopted policies wherein construction of multilane divided arterials in rural areas will exclude provision of signalized intersections in favor of interchanges. Nearly every highway agency has intersections where the recommended strategy is applicable.
Issues Affecting Implementation Time	Simple changes in intersection traffic control, such as all-way stop control, can be made in 3 months or less. Projects involving more extensive construction, such as provision of roundabouts, or even construction of grade-separated interchanges, may involve a project development process up to 4 years or more in duration.
Costs Involved	Most construction alternatives, such as jug handles, grade separations, interchanges, and roundabouts, would require significant investment. In many cases right-of-way acquisition would be a part of this. Projects of this type can cost from several million dollars to over $10 million.
Training and Other Personnel Needs	Training on signalized intersection planning and design should include alternatives to signalization. Many alternatives to signalization are relatively new and unfamiliar to highway agency staff. Understanding the engineering principles and expected performance of new alternatives such as roundabouts, jug handles, and arterial-to-arterial interchanges will be important.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies to improve safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

FHWA-RD-00-067, *Roundabouts: An Informational Guide* (Robinson, Rodegerdts, Scarborough, Kittelson, Troutbeck, Brilon, Bondzio, Courage, Kyte, Mason, Flannery, Myers, Bunker, and Jacquemart, 2000).

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

Strategy 17.1 F2—Provide All-Way Stop Control at Appropriate Intersections (P)

General Description

All-way stop control can reduce right-angle and turning collisions at unsignalized intersections by providing more orderly movement at an intersection, reducing through and turning speeds, and minimizing the safety effect of any sight distance restrictions that may be present. However, all-way stop control is suitable only at intersections with moderate and relatively balanced volume levels on the intersection approaches. Under other conditions, the use of all-way stop control may create unnecessary delays and aggressive driver behavior (i.e., deliberate ignoring of the stop control).

EXHIBIT V-44
Strategy Attributes for Providing All-Way Stop Control at Appropriate Intersections (P)

Technical Attributes	
Target	The target for this strategy should be unsignalized intersections with patterns of right-angle and turning collisions and moderate and relatively balanced volume on the intersection approaches.
Expected Effectiveness	A recent review of the effectiveness of various strategies in reducing crashes concluded that conversion from two-way to all-way stop control could reduce total intersection crashes by 53 percent (Harwood et al., 2000). However, this estimate is based on limited data, and further research to quantify the safety effectiveness of all-way stop control under a broad range of conditions would be desirable.
Key to Success	A key to success is identifying moderate volume situations in which all-way stop control will operate efficiently, without substantially more delay than a signalized intersection. It is important that the driving public be alerted to the change of control during a transition period.
Potential Difficulties	Not every two-way stop-controlled intersection should be considered as a candidate for all-stop control. This strategy should be used selectively, recognizing patterns and volumes of traffic and potentially adverse reaction by the driving population to being stopped for no apparent reason. If drivers encounter substantial delays, they may become impatient and act irrationally, which can lead to crash patterns of the type that the strategy is intended to correct.
Appropriate Measures and Data	A key process measure is the number of intersections at which all-way stop controls are installed. Crash frequency and severity, by type, are key safety effectiveness measures. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	Drivers understand all-way stop control with no need for special public education campaigns. However, public information should be distributed about any forthcoming change in traffic control.

EXHIBIT V-44 (Continued)
Strategy Attributes for Providing All-Way Stop Control at Appropriate Intersections (P)

Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agency policies on traffic control devices should address the appropriate uses of all-way stop control. Nearly any highway agency can participate in the implementation of this strategy. While the strategy is applicable to rural, urban, and suburban locations, the greatest need is for agencies that operate extensive systems of urban and suburban arterials.
Issues Affecting Implementation Time	All-way stop control can normally be implemented with just a change in signing at the intersection, or on intersection approaches, typically in 3 months or less.
Costs Involved	The costs involved in converting to all-way stop control are relatively low. However, an agency's maintenance costs may increase.
Training and Other Personnel Needs	Appropriate use of all-way stop control should be addressed in highway agency training courses on traffic control devices.
Legislative Needs	Some states restrict or prohibit the use of all-way stop control. While all-way stop control should not be overused, revising legislation that restricts or prohibits this strategy may be appropriate.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* (Harwood, Council, Hauer, Hughes, and Vogt, 2000).

Strategy 17.1 F3—Provide Roundabouts at Appropriate Locations (P)

General Description

Roundabouts provide an important alternative to signalized and all-way stop-controlled intersections. Modern roundabouts differ from traditional traffic circles in that they operate in such a manner that traffic entering the roundabout must yield the right-of-way to traffic already in it. Roundabouts can serve moderate traffic volumes with less delay than signalized or all-way stop-controlled intersections because traffic can normally traverse the roundabout without stopping. Design guidance for roundabouts is provided in a recent FHWA publication (Robinson et al., 2000, http://www.tfhrc.gov///safety/00068.pdf).

EXHIBIT V-45
Strategy Attributes for Providing Roundabouts at Appropriate Locations (P)

Technical Attributes	
Target	The target locations for roundabouts should be moderate-volume unsignalized intersections. Such locations are candidates for signalization lacking an alternative such as a roundabout. Whether such intersections have existing crash patterns or not, the roundabout provides an alternative to signalization, with its inherent pattern of rear-end and other collision types.
Expected Effectiveness	Provision of modern roundabouts is a relatively new strategy in the United States, although roundabouts have been used overseas for many years. Recent research has estimated the effectiveness of installing a modern roundabout at previously unsignalized locations at a 38-percent reduction in total crashes, a 76-percent reduction in injury crashes, and a 90-percent reduction in fatal and incapacitating-injury crashes (Persaud et al., 2001).
Key to Success	A key to success is designing the roundabout and its approaches in accordance with accepted geometric design and traffic control criteria (Robinson et al., 2000).
Potential Difficulties	The major potential pitfall is the difficulty of providing pedestrian facilities, particularly for visually impaired pedestrians, because the roundabout violates the normal expectancy. Provision of bicycle facilities at roundabouts may also be a challenge. Roundabouts may not be a viable alternative in many suburban and urban settings where right-of-way is limited. Also, public understanding of roundabouts is limited in the United States, and a strategy to employ roundabouts may require substantial education of the general public and local units of government. Finally, construction of a roundabout would typically be a major project, requiring the environmental process, right-of-way acquisition, and implementation under an agency's long-term capital improvement program. Roundabouts thus represent only a long-term solution.
Appropriate Measures and Data	A key process measure is the number of intersections where roundabouts are installed. Crash frequency and severity, by type, are key safety effectiveness measures. Both total crashes and crash types potentially affected by the particular control or treatment change should be analyzed separately, where appropriate. Operation performance measures, including delay, should also be included. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	Roundabouts are a relatively new treatment, and an extensive public information and education effort should be made, especially when roundabouts are first used in a particular area.

EXHIBIT V-45 (Continued)
Strategy Attributes for Providing Roundabouts at Appropriate Locations (P)

Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Roundabouts are new to most highway agencies. The use of roundabouts as a widespread strategy for safety improvements needs first to be understood and accepted within a highway agency, with appropriate revisions to design policies and standards to reflect the roundabout as accepted practice. The use of roundabouts in the United States is a relatively recent phenomenon. Some states may not have established design policies or warrants for this design alternative. Furthermore, some design policies and warrants may need updating, especially if this strategy is adopted for broad application in the state. Nearly any highway agency can participate in the implementation of this strategy. While the strategy is applicable to rural, urban, and suburban locations, the greatest need is for agencies that operate extensive systems of urban and suburban arterials.
Issues Affecting Implementation Time	Provision of a roundabout is a major design change that requires substantial project development and may require right-of-way acquisition. These activities may require 4 years or longer to implement.
Costs Involved	Costs are variable, but construction of a roundabout to replace an existing intersection could run from several hundred thousand dollars to over $1 million based on the project location and constraints.
Training and Other Personnel Needs	Training for highway agency personnel in roundabout design should be provided as part of highway agency training related to geometric design of intersections.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	Roundabouts are a unique approach to intersection traffic control and are not generally compatible with other types of intersection geometric improvements and other types of traffic control.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

FHWA-RD-00-067, *Roundabouts: An Informational Guide* (Robinson, Rodegerdts, Scarborough, Kittelson, Troutbeck, Brilon, Bondzio, Courage, Kyte, Mason, Flannery, Myers, Bunker, and Jacquemart, 2000).

Transportation Research Record 1751, “Safety Effect of Roundabout Conversions in the United States: Empirical Bayes Observational Before-After Study” (Persaud, Retting, Garder, and Lord, 2001), Transportation Research Board of the National Academies.

Insurance Institute for Highway Safety, *Crash Reductions Following Installation of Roundabouts in the United States* (Persaud, Retting, Garder, and Lord, 2000).

NCHRP Synthesis of Highway Practice 264: Modern Roundabout Practice in the United States (Jacquemart, 1998), Transportation Research Board of the National Academies.

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets* (2001).

Objective 17.1 G—Improve Driver Compliance with Traffic Control Devices and Traffic Laws at Intersections

Strategy 17.1 G1—Provide Targeted Enforcement to Reduce Stop Sign Violations (T)

General Description

Enforcement options are a potential countermeasure to unsafe and illegal motorist behavior at intersections. Studies report the reduction of traffic law violation when enforcement is used (Pline, 1999). 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. Traffic law enforcement methods (http://www.nhtsa.dot.gov/people/injury/enforce/DESKBK.html) vary depending upon the type of program being implemented.

EXHIBIT V-46
Strategy Attributes for Providing Targeted Enforcement to Reduce Stop Sign Violations (T)

Technical Attributes	
Target	The target for this strategy should be intersections where stop sign violations and patterns of crashes related to stop sign violations have been observed. Crash types potentially related to stop sign violations include right-angle and turning collisions.
Expected Effectiveness	This strategy is known to be effective in reducing traffic law violations. Programs within the United States have been found to result in decreases in violations of between 23 and 83 percent (Pline, 1999). However, the safety effectiveness of such decreases in violation rates has not been quantified. Enforcement agencies have generally found that the effectiveness of increased enforcement at specific locations has a relatively short duration of effectiveness—measured in days or weeks, rather than months or years. Further research to quantify the safety effectiveness of enforcement activities would be desirable.
Key to Success	A key to success for this strategy is identifying the intersections that can potentially benefit from increased enforcement. Such intersections should have a combination of high stop sign 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 law enforcement agency(ies) in the jurisdiction be involved jointly in planning and operating the program.

EXHIBIT V-46 (Continued)
Strategy Attributes for Providing Targeted Enforcement to Reduce Stop Sign Violations (T)

	The success of any enforcement program depends substantially on the performance of the officer in the field. It is important that all officers involved be told of the objectives and expected benefits of the program and that they be given regular feedback on their effectiveness. It is also important to have interaction with the court systems operating in the jurisdiction so that the judiciary understands the objectives. It may also be possible in some cases to involve the judiciary in planning and implementing the program. This should include roll-call training of front line officers regarding the safety benefits of the program.
Potential Difficulties	The major potential difficulty with a program of increased enforcement is the potential for diverting police officers from more productive work if the locations for stop sign enforcement are not selected carefully. In addition, care must be taken to identify appropriate and safe locations to stop violators to issue citations. Finally, if the court system does not adequately convict and apply sufficiently strong sanctions to the cited offenders, the program will lose its effectiveness.
Appropriate Measures and Data	A key process measure is the number of intersections where increased enforcement is applied. Other process measures include the number of officer hours of targeted enforcement provided, the number of additional citations issued, the reduction in violation rate, and the resulting number of additional convictions. Crash frequency and severity data, by type, are key safety effectiveness measures. Data for these measures and data on the frequency of violations, by type, are needed. Traffic volume data are needed to represent exposure. Where feasible, the effect of increased enforcement on total crashes and crash types potentially related to stop sign violations should be evaluated separately.
Associated Needs	There is a potential need for public information and education about the reasons for the strategies selected, particularly when targeted enforcement techniques are used in an area for the first time. A special informational campaign may be needed for the court system.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Crash analysis procedures should include methods to identify the need for increased enforcement of stop sign violations. It is important that the program be handled in a coordinated manner among the highway, law enforcement, and judicial agencies. Nearly every highway and police agency has intersections under its jurisdiction where this strategy can be applied.
Issues Affecting Implementation Time	Targeted enforcement can be implemented in a short period of time. Identified problems can be addressed almost immediately if enforcement is available.
Costs Involved	There is almost no capital cost involved in increased enforcement, but staff hours and vehicle operating costs may be substantial. Funding may be available at the national level through NHTSA.

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EXHIBIT V-46 (Continued)
Strategy Attributes for Providing Targeted Enforcement to Reduce Stop Sign Violations (T)

Training and Other Personnel Needs	Training for highway engineers, safety analysts, and police officers should address targeted enforcement of stop sign violations. This training should include roll-call training of front line officers regarding the safety benefits of the program.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies to improve safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Institute of Transportation Engineers, *Traffic Engineering Handbook* (Pline, 1999).

NCHRP Synthesis of Highway Practice 219: Photographic Enforcement of Traffic Laws (Blackburn and Gilbert, 1995), Transportation Research Board of the National Academies.

Strategy 17.1 G2—Provide Targeted Public Information and Education on Safety Problems at Specific Intersections (T)

General Description

Providing targeted public information and education on safety problems at specific intersections is a preventive measure that can help improve driver compliance with traffic control devices and traffic laws at intersections. Public information and education programs often add effectiveness to targeted enforcement programs, as well. However, this strategy stresses a separate use of the method.

EXHIBIT V-47
Strategy Attributes for Providing Targeted Public Information and Education on Safety Problems at Specific Intersections (T)

Technical Attributes	
Target	The target for this strategy should be drivers using intersections that have experienced a large number of safety problems.
Expected Effectiveness	There are no established quantitative measures of the safety effects of providing targeted public information and education on safety problems at specific intersections.

EXHIBIT V-47 (Continued)
Strategy Attributes for Providing Targeted Public Information and Education on Safety Problems at Specific Intersections (T)

Key to Success	A key to success for this strategy is reaching as much of the targeted audience as possible, whether it is through television, radio, distribution of flyers, driver education classes, or other methods. Targeted drivers need to be defined in terms of both 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.
Potential Difficulties	A potential difficulty with this strategy is that the public information and education campaign may not reach many members of the targeted audience. It is often difficult to identify and focus upon a subset of the driving population using a specific intersection. Therefore, an areawide program is often the preferred approach.
Appropriate Measures and Data	A key process measure is the number of intersections where targeted public information and education activities on safety problems are applied. Other process measures include the number of public information and education activities carried out and driver awareness of the campaign. Crash frequency and severity, by type, are key safety effectiveness measures. Both total crashes and crash types potentially affected by the public information and education campaign should be analyzed separately, where appropriate. Studying attributes of drivers involved in the crashes may help identify specific parts of the population on which to focus. This may affect the media channels and methods used. Crash frequency and severity data are needed. Traffic volume data are needed to represent exposure.
Associated Needs	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 part of project planning.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Highway agency policies on intersection safety should address the appropriate uses of public information and education campaigns. If a media specialist is not available within the agency, it may be necessary to involve another agency or use a private media consultant. Nearly every highway agency can participate in the implementation of this strategy. The strategy is applicable to rural, urban, and suburban locations.
Issues Affecting Implementation Time	Targeted public information and education campaigns should be well planned before implementation. The more time invested in the planning process, the greater the likelihood of the strategy reaching the appropriate audience and being effective. This strategy can be implemented in a relatively short period of time, typically from 6 months to a year.
Costs Involved	The costs involved in a public-information and education campaign vary by the type of distribution (e.g., television, radio, newspaper, etc.), but are generally less expensive than many other intersection safety improvement strategies. Funding may be available at the national level through NHTSA or FHWA.

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EXHIBIT V-47 (Continued)
Strategy Attributes for Providing Targeted Public Information and Education on Safety Problems at Specific Intersections (T)

Training and Other Personnel Needs	While the appropriate use of public information and education campaigns should be addressed in highway agency training courses on intersection safety, consultants who specialize in such campaigns are often contracted to design and implement them.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies to improve safety at unsignalized intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Institute of Transportation Engineers, *Traffic Engineering Handbook* (Pline, 1999).

Illinois Department of Transportation, *Selective Traffic Enforcement Program Champaign—Interim Evaluation Report* (Dougherty, 1977).

Journal of Traffic Medicine, Vol. 18, No. 3, "The Massachusetts Saving Lives Program: Six Cities Widening the Focus from Drunk Driving to Speeding, Reckless Driving, and Failure to Wear Safety Belts" (Hingson, Howland, Schiavone, and Damiata, 1990).

Traffic Safety Journal, No. 3, "DOT Launches Campaign to Curb Drunk Driving Deaths" (Karr, 2000), National Safety Council.

Traffic Safety Journal, No. 4, "Aggressive Driving: One City's Solution" (Johnson, 2000), National Safety Council.

Human Factors and Ergonomics Society 42nd Annual Meeting, Proceedings, *The Effectiveness of Educating Pedestrians About Their Own Nighttime Visibility* (Tyrrell, and Patton, 1998).

ITE Journal, Vol. 61, No. 1, "Develop Your Own In-House Public Relations Program" (Larsen, 1991).

Objective 17.1 H—Reduce Operating Speeds on Specific Intersection Approaches

Strategy 17.1 H1—Provide Targeted Speed Enforcement (P)

General Description

Law enforcement is considered an important contributor for maintaining traffic safety. However, limited resources, such as staff and funds, constrain the efforts of police providing targeted speed enforcement. Studies have shown that speed warning and enforcement help reduce the mean speed and consequently the number of injury, fatal, and property-damage-only crashes in which unsafe speed is the primary collision factor.

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. Traffic law enforcement methods (http://www.nhtsa.dot.gov/people/injury/enforce/DESKBK.html) vary depending upon the type of program being implemented.

EXHIBIT V-48
Strategy Attributes for Providing Targeted Speed Enforcement (P)

Technical Attributes	
Target	The target for this strategy is intersections where speed violations and patterns of crashes related to speed violations are observed. Crash types potentially related to speed violations include right-angle, rear-end, and turning collisions.
Expected Effectiveness	The effectiveness of this strategy has been established by numerous studies (De Waard and Rooijers, 1994). The most effective enforcement is the on-view stopping and ticketing of offenders, as opposed to automated enforcement where fines are mailed on the basis of the car's license plate number. Enforcement agencies have generally found that the effectiveness of increased enforcement at specific locations has a relatively short duration of effectiveness—measured in days or weeks, rather than months or years.
Key to Success	A key to success of this strategy is planning the enforcement and prioritizing the intersections that need it (*TRB Special Report 254,* 1998). 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 law enforcement agency(ies) in the jurisdiction be involved jointly in planning and operating the program. The success of any enforcement program depends substantially on the performance of the officer in the field. It is important that all officers involved be told of the objectives and expected benefits of the program and that they be given regular feedback on their effectiveness. It is also important to interact with the court systems operating in the jurisdiction so that the judiciary understands the objectives. It may also be possible in some cases to involve the judiciary in planning and implementing the program.
Potential Difficulties	The major potential difficulty with a program of targeted speed enforcement is the potential for diverting police officers from more productive work if the locations for speed enforcement are not selected carefully. In addition, care must be taken to identify appropriate and safe locations to stop violators and issue citations. Finally, if the court system does not adequately convict and apply sufficiently strong sanctions to the cited offenders, the program will lose its effectiveness.

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EXHIBIT V-48 (Continued)
Strategy Attributes for Providing Targeted Speed Enforcement (P)

Appropriate Measures and Data	A key process measure is the number of intersections at which targeted speed enforcement is applied. Other process measures include the number of officer hours of targeted enforcement provided, the number of additional citations issued, and the resulting number of additional convictions. Key speed-related process measures include mean speed, 85th-percentile speed, and percentage of drivers exceeding the speed limit by specific amounts; these measures can be determined from speed studies. Crash frequency and severity data, by type, are key safety effectiveness measures. Data describing these crashes and data on the frequency of violations are needed. Traffic volume data are needed to represent exposure. Where feasible, the effect of targeted speed enforcement on total crashes and crash types potentially related to speed violations should be evaluated separately.
Associated Needs	There is a potential need for public information and education about the reasons for the targeted enforcement, particularly when targeted enforcement techniques are used in an area for the first time. A special informational campaign may be needed for the court system.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Crash analysis procedures should include methods to identify the need for targeted speed enforcement. It is important that the program be handled in a coordinated manner among the highway, law enforcement, and judicial agencies. Nearly every highway and police agency has intersections under its jurisdiction where this strategy can be applied. Any speed control program should be based upon well-established policies and procedures regarding the establishment of speed limits. Speed limits should reflect sound principles and the application of current scientific knowledge on what is considered safe and should protect against demands that are based solely on political considerations.
Issues Affecting Implementation Time	Targeted speed enforcement can be implemented in a short period of time. Identified problems can be addressed almost immediately if enforcement is available.
Costs Involved	There are almost no capital costs involved in speed enforcement, but staff hours and vehicle operating costs may be substantial. Funding may be available at the national level through NHTSA.
Training and Other Personnel Needs	Training for highway engineers, safety analysts, and police officers should address targeted speed enforcement. This training should include roll-call training of front line officers regarding the safety benefits of the program.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Accident Analysis and Prevention, Volume 126, Issue 6, "An Experimental Study to Evaluate the Effectiveness of Different Methods and Intensities of Law Enforcement on Driving Speed on Motorways" (De Waard and Rooijers, 1994).

TRB Special Report 254: Managing Speed: Review of Current Practice for Setting and Enforcing Speed Limits (1998), Transportation Research Board of the National Academies.

Institute of Transportation Engineers, *Traffic Engineering Handbook* (Pline, 1999).

Transportation Research Record 1560, "Automatic Speed Management in the Netherlands" (Oei, 1996), Transportation Research Board of the National Academies.

Illinois Department of Transportation, *Selective Traffic Enforcement Program Champaign–Interim Evaluation Report* (Dougherty, 1977).

NCHRP Synthesis of Highway Practice 219: Photographic Enforcement of Traffic Laws (Blackburn and Gilbert, 1995), Transportation Research Board of the National Academies.

Strategy 17.1 H2—Provide Traffic Calming on Intersection Approaches through a Combination of Geometric and Traffic Control Devices (T)

General Description

The goals of traffic calming are typically to reduce vehicle speeds, traffic volume, or both. Volume control measures limit traffic by restricting vehicle access. They include full street closures, half closures, diagonal diverters, median barriers, and forced-turn islands. Speed control measures can be divided into three types: vertical, horizontal, and narrowing. Vertical speed controls include speed humps, which are parabolic, circular, or sinusoidal mounds placed across a roadway. Speed tables are basically flat-topped speed humps. Horizontal speed controls slow traffic by requiring vehicles to shift direction in order to maneuver around them. The most common is the traffic circle. Narrowing roadways controls speed by reducing the amount of lateral space in which vehicles can maneuver.

Despite steady growth in the use of traffic-calming devices (see http://www.fhwa.dot.gov/environment/tcalm and http://www.ite.org/traffic/index.html), few guidelines have been established for their construction in the United States. Design, however, is only one factor in the ultimate success or failure of a traffic-calming measure. Equally important are (1) careful planning to determine whether the measure is a viable means of improving overall safety and mobility, (2) determining what impact the measure may have on street maintenance and emergency vehicles, (3) determining whether the measure will be self-enforcing (that is, not require additional policing), and (4) estimating how the measure will affect surrounding streets and neighborhoods. All of these issues need to be addressed before implementation. The early and continuous involvement of adjacent property owners, neighborhood groups, and the relevant city agencies is crucial (Knapp, 2000).

EXHIBIT V-49
Strategy Attributes for Providing Traffic Calming on Intersection Approaches through a Combination of Geometric and Traffic Control Devices (T)

Technical Attributes	
Target	The target of this strategy is to reduce speeds on specific intersection approaches. Crash types potentially related to speed violations include right-angle, rear-end, and turning collisions.
Expected Effectiveness	The effectiveness of this strategy has been established for surrogate measures in several specific cases. See for example the work of Kallberg and Ranta (2000). Results from this study showed that the impacts on mean speed at single sites varied from a 5 km/h increase to a 27 km/h decrease.
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.
Potential Difficulties	A potential difficulty associated with traffic-calming measures is the lack of established guidelines for their construction in the United States. Traffic-calming measures are also often controversial, especially when used to divert traffic from one road or street to another.
Appropriate Measures and Data	A key process measure is the number of intersections at which traffic-calming measures are applied. Crash frequency and severity data, by type, are key safety effectiveness measures. Data on these measures and on the frequency of violations are needed. Traffic volume data are needed to represent exposure. Where feasible, the effect of traffic calming on total crashes and crash types potentially related to speed violations should be evaluated separately.
Associated Needs	Appropriate public information and education is fundamental for the effectiveness of this strategy, particularly when traffic-calming techniques are used in an area for the first time.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Crash analysis procedures should include methods to identify the need for targeted speed enforcement. A set of policies is needed regarding warrants, design, and operation of traffic-calming measures. Nearly every highway agency has intersections under its jurisdiction at which this strategy can be applied.
Issues Affecting Implementation Time	The implementation time for traffic-calming measures will depend upon the type of measure used. Some types of traffic-calming improvements may take 3 months or less (e.g., introducing speed humps) while others, especially when geometric improvements are required (e.g., traffic circles), may take 1 year or more.
Costs Involved	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 (e.g., speed humps) while others that require geometric design improvements and/or acquisition of right-of-way may be moderate cost. To the extent required by law, individual property owners may be required to share in the cost of providing traffic-calming measures in their area.

EXHIBIT V-49 (Continued)
Strategy Attributes for Providing Traffic Calming on Intersection Approaches through a Combination of Geometric and Traffic Control Devices (T)

Training and Other Personnel Needs	Training for this strategy is not currently available and needs to be established.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Civil Engineering, Volume 70, Number 1, "Traffic-Calming Basics" (Knapp, 2000).

2nd International Symposium on Highway Geometric Design, Proceedings, "Impacts of Urban Speed-Reducing Measures" (Kallberg and Ranta, 2000).

Strategy 17.1 H3—Post Appropriate Speed Limits on Intersection Approaches (T)

General Description

Speed is often cited as one of the major contributing factors to accidents. It is not necessarily the rate of speed that a vehicle is traveling that causes an accident, but the speed variance between vehicles. In a review of speed and crash probability, Waller (2002) indicates that there is extensive evidence that speed variance increases crash probability. Due to the number of speed-related accidents, it is important for agencies to post appropriate speed limits on intersection approaches to convey consistent messages to drivers. Posting an appropriate speed limit on an approach may involve reducing the speed limit in the vicinity of the intersection or posting an advisory speed (see Exhibit V-50). Guidelines for speed zoning, along with supporting information, may be found at http://www.ibiblio.org/rdu/ite-szg.html.

EXHIBIT V-50
Advisory Speed

EXHIBIT V-51
Strategy Attributes for Posting Appropriate Speed Limits on Intersection Approaches (T)

Technical Attributes	
Target	The target of this strategy is to reduce speed-related accidents near intersections.
Expected Effectiveness	The safety effectiveness of posting appropriate speed limits on intersection approaches has not been quantified.
Key to Success	The keys to success are determining the appropriate speed limit for intersection approaches (based upon the functional class of the roadways, average operating speeds, traffic volume, geographical area, and roadside characteristics) and determining whether the speed limit should be reduced in the vicinity of the intersection.
Potential Difficulties	Several potential difficulties exist. First, the posted speed limit on an approach may be appropriate, but some studies have shown that this does not guarantee that speeds will change. Second, when it is determined that the current posted speed limit is inappropriate and should be changed, significant variances in speed may occur in the transition period after the new speed limit is posted until drivers become accustomed to the new posted speed.
Appropriate Measures and Data	A key process measure is the number of intersection approaches at which a new speed limit was posted.

EXHIBIT V-51 (Continued)
Strategy Attributes for Posting Appropriate Speed Limits on Intersection Approaches (T)

	Crash frequency and severity data, by type, are key safety effectiveness measures. Data on these measures and on the frequency of speed violations are needed. Traffic volume data are needed to represent exposure. Where feasible, the effect of posted speed limit on total crashes and speed-related crashes should be evaluated separately. Speed studies will need to be conducted to evaluate the need for changing posted speed limits on approaches.
Associated Needs	None identified.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies may wish to reevaluate their policies for determining appropriate speed limits on intersection approaches.
Issues Affecting Implementation Time	The implementation time for posting appropriate speed limits should take 3 months or less.
Costs Involved	The costs involved in posting appropriate speed limits on intersection approaches are minimal. The costs involve conducting the necessary speed studies and costs for replacing the signs.
Training and Other Personnel Needs	Training for highway engineers should address the agency's policy on determining appropriate speed limits.
Legislative Needs	Legislated speed limits by road classification are determined by state legislatures and city councils for state and local roads, respectively. There may be a need to revise existing laws.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at intersections, especially targeted speed enforcement, so that drivers obey the posted speed limit.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following sources (full reference citations are provided in Section VII):

Transportation Quarterly, Vol. 56 No. 3, "Speed Limits: How Should They Be Determined?" (Waller, 2002).

TRB Special Report 254: Managing Speed: Review of Current Practice for Setting and Enforcing Speed Limits (1998), Transportation Research Board of the National Academies.

ITE Speed Zoning Guidelines, ITE Committee 4M-25 Speed Zone Guidelines, Recommended Practice, Final Draft Version, undated, taken from http://www.ibiblio.org/rdu/ite-szg.html.

Objective 17.1 I—Guide Motorists More Effectively through Complex Intersections

Strategy 17.1 I1—Provide Turn Path Markings (T)

General Description

At most intersections, pavement markings are provided on the intersection approaches, but the pavement markings end near the stop line. Rarely are pavement markings extended into or continued through intersections. At complex intersections, however, it may be beneficial to provide motorists with additional information to help with vehicle positioning through the intersections. In particular, it may be desirable to extend pavement markings through intersections that have offset approaches, are skewed, have multiple turn lanes, or are located at unsignalized ramp terminals. This approach is especially useful for delineating vehicle turning paths through an intersection. The MUTCD provides guidance on extending pavement markings through intersections.

EXHIBIT V-52
Strategy Attributes for Providing Turn Path Markings (T)

Technical Attributes	
Target	The target of this strategy is to reduce accidents at complex intersections primarily related to vehicle positioning (i.e., sideswipe crashes).
Expected Effectiveness	The safety effectiveness of extending pavement markings through intersections has not been evaluated.
Key to Success	A key to success is to determine which maneuvers drivers are having trouble performing and to define and mark the appropriate turning paths. This may require extensive review of individual crash reports, as well as observations and measurements at a site. Proper maintenance of the markings will also be important to the success of this strategy.
Potential Difficulties	If too many markings are extended through the intersection, the intersection could become very confusing for drivers. In cases where snow and ice collect on the road, the effectiveness of the markings may be reduced.
Appropriate Measures and Data	A key process measure is the number of intersections where pavement markings were extended through the intersections. Crash frequency and severity, by type, are key safety effectiveness measures. Both total crashes and crash types potentially related to vehicle positioning or guidance should be analyzed separately. Traffic volume data are needed to represent exposure. Changes in driver behavior (e.g., paths taken through the intersection) may be used as a surrogate for interim analysis of effectiveness.
Associated Needs	None identified.

EXHIBIT V-52 (Continued)
Strategy Attributes for Providing Turn Path Markings (T)

Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies may need to adopt a policy for extending pavement markings through intersections. Guidance is provided in the MUTCD.
Issues Affecting Implementation Time	The implementation time for providing turn path markings could be 3 months or less.
Costs Involved	The costs involved in providing turn path markings are minimal. Agencies may experience additional maintenance costs.
Training and Other Personnel Needs	Providing turn path markings through intersections should be addressed in highway agency training concerning traffic control devices and pavement markings.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices for Streets and Highways* (2000).

Strategy 17.1 I2—Provide Double Yellow Centerline on the Median Opening of a Divided Highway at Intersections (T)

General Description

Undesirable driving behaviors often occur on the section of roadway at the opening of divided highways at intersections. Common types of undesirable driving behaviors include the following (Harwood et al., 1995):

- Side-by-side queuing on the median roadway by vehicles in the same travel direction,
- Stopping at an angle on the median roadway, and
- Encroaching on a through lane of the divided highway.

This strategy is designed to minimize the occurrence of the first two maneuvers (side-by-side queuing and angle stopping). Side-by-side queuing occurs when one vehicle is waiting on the median roadway for an opportunity to cross or enter the far roadway of a divided highway, and a second vehicle arrives and stops beside rather than behind the first vehicle. Side-by-side queuing can lead to driver confusion about which of the two vehicles is to proceed first and, thus, can lead to potential conflicts. Angle stopping occurs when a vehicle stops on the median roadway at some angle other than perpendicular to the through lanes of the divided highway. Stopping at an unusual angle is undesirable because the vehicle may be hit by another vehicle from any of several directions and because other drivers may be confused about the intended path of that vehicle.

Providing a double yellow centerline on the median roadway at the opening can be helpful to define the vehicle paths at divided highway intersections. A double yellow centerline on the median roadway provides visual continuity with the centerline of the crossroad approaches and helps to define a desired path for drivers. The presence of a double yellow centerline on the median roadway should minimize the temptation for drivers to queue side-by-side or to cut over to the left side of the median roadway and stop at an angle when making a left turn.

EXHIBIT V-53
Strategy Attributes for Providing a Double Yellow Centerline on the Median Opening of a Divided Highway (T)

Technical Attributes	
Target	The target of this strategy is to reduce accidents caused by side-by-side queuing and angle stopping within the median opening at a crossing roadway.
Expected Effectiveness	The safety effectiveness of providing a double yellow centerline on the median opening of a divided highway has not been quantified. However, the presence of a double yellow centerline should minimize side-by-side queuing and angle stopping and thus reduce driver confusion near the intersection.
Key to Success	When providing a double yellow centerline on the median opening of a divided highway, the median should be of sufficient width (at least 100 feet) so that vehicles can follow a desired path. Proper maintenance of the striping will be important to the strategy's success. Presence of snow or ice on the roadway area may significantly reduce the strategy's effectiveness at critical times.
Potential Difficulties	If the median roadway is narrow and a double yellow centerline is provided, it is possible that as vehicles queue one behind the other in the median, portions of vehicles will stick out (overhang) into the through roadway.
Appropriate Measures and Data	A key process measure is the number of intersections where double yellow centerlines were provided on the median roadway of a divided highway. Crash frequency and severity, by type, are key safety effectiveness measures. Both total crashes and crash types potentially related to side-by-side queuing and angle stopping should be analyzed separately. Traffic volume data are needed to represent exposure. A surrogate measure is change in driver turning and queuing behaviors measured in the median opening at the intersection.
Associated Needs	None identified.

EXHIBIT V-53 (Continued)
Strategy Attributes for Providing a Double Yellow Centerline on the Median Opening of a Divided Highway (T)

Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	A highway agency may need to adopt a policy to determine when double yellow centerlines on median roadways of divided highways are warranted and appropriate. Guidance is provided in *NCHRP Report 375* (Harwood et al., 1995).
Issues Affecting Implementation Time	The implementation time for this strategy is 3 months or less.
Costs Involved	The costs involved in providing double yellow centerlines on median roadways are minimal. Agencies may experience additional maintenance costs.
Training and Other Personnel Needs	Providing double yellow centerlines on median roadways should be addressed in highway agency training concerning traffic control devices and pavement markings.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

NCHRP Report 375: Median Intersection Design (Harwood, Pietrucha, Wooldridge, Brydia, and Fitzpatrick, 1995), Transportation Research Board of the National Academies.

Strategy 17.1 I3—Provide Lane Assignment Signing or Marking at Complex Intersections (T)

General Description

Sometimes, as drivers approach a complex intersection, they have difficulty determining the appropriate lane from which to perform a certain maneuver. This can cause indecision among drivers and result in maneuvers being made from certain lanes that are unexpected. These maneuvers could potentially lead to accidents. Accident patterns that are characteristic of driver indecision related to lane assignment include rear-end and sideswipe accidents on intersection approaches and potentially angle accidents when a driver performs an unexpected maneuver from an inappropriate lane (e.g., a vehicle makes a left turn from a through lane).

Providing lane assignment signs (or markings) to guide motorists through complex intersections can alleviate this confusion and lead to safer driving conditions. Pavement markings are often used to supplement lane assignment signs.

EXHIBIT V-54
Strategy Attributes for Providing Lane Assignment Signing or Marking at Complex Intersections (T)

Technical Attributes	
Target	The target of this strategy is to reduce accidents caused by driver indecision in lane assignment.
Expected Effectiveness	The safety effectiveness of providing lane assignment signing or marking has not been quantified. However, the presence of lane assignment signs and/or markings should reduce driver confusion near the intersection concerning proper lane assignment and minimize the number of unexpected maneuvers from designated lane groups.
Key to Success	Lane assignment signs and/or markings need to be visible to drivers. Overhead signs are preferred to post-mounted signs (placed on the shoulder) because the overhead signs can be placed directly over the lanes to which they apply. In addition, the lane assignment signing/marking should be placed far enough in advance of the intersection so that vehicles can maneuver to the appropriate lane. Proper maintenance of the markings will be important to the strategy's success. Presence of snow or ice on the roadway area may significantly reduce the strategy's effectiveness at critical times.
Potential Difficulties	Unless the lane assignment signs are mounted on existing posts, additional hardware will have to be placed on the roadside. This hardware becomes an additional object that a vehicle may strike if it leaves the roadway.
Appropriate Measures and Data	A key process measure is the number of intersections where lane assignment signs/markings are provided. Crash frequency and severity, by type, are key safety effectiveness measures. Both total crashes and crashes potentially related to lane assignment (e.g., rear-end, sideswipe, and angle accidents) should be analyzed separately. Traffic volume data are needed to represent exposure. A surrogate measure is change in driver turning behavior measured through the intersection.
Associated Needs	None identified
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	None identified.
Issues Affecting Implementation Time	The implementation time for post-mounted lane assignment signs should be 3 months or less. It may take up to a year to provide overhead signing.
Costs Involved	The costs involved in providing lane assignment signs are minimal when post-mounted signs and pavement markings are used. The cost of overhead signing is moderate. Agencies may experience additional maintenance costs.
Training and Other Personnel Needs	Providing lane assignment signs/markings should be addressed in highway agency training concerning traffic control devices and pavement markings.
Legislative Needs	None identified.

EXHIBIT V-54 (Continued)
Strategy Attributes for Providing Lane Assignment Signing or Marking at Complex Intersections (T)

Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with most other strategies for improving safety at intersections.
Other Key Attributes to a Particular Strategy	None identified.

For further information about this strategy, see the following source (full reference citations are provided in Section VII):

Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (MUTCD) (2000).

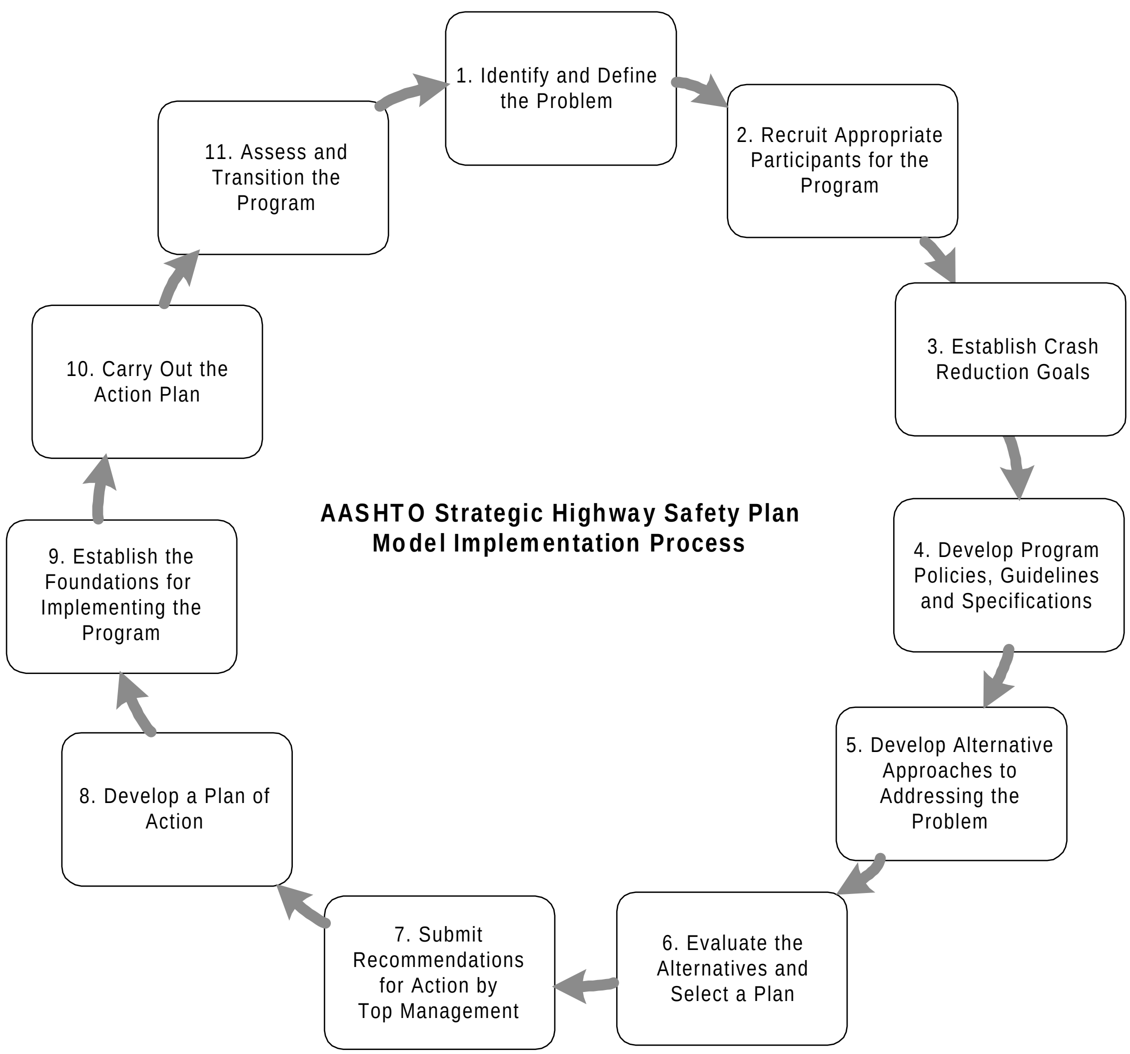
SECTION VI

Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

Outline for a Model Implementation Process

Exhibit VI-1 gives an overview of an 11-step model process for implementing a program of strategies for any given emphasis area of the AASHTO Strategic Highway Safety Plan. After a short introduction, each of the steps is outlined in further detail.

EXHIBIT VI-1



Purpose of the Model Process

The process described in this section is provided as a model rather than a standard. Many users of this guide will already be working within a process established by their agency or working group. It is not suggested that their process be modified to conform to this one. However, the model process may provide a useful checklist. For those not having a standard process to follow, it is recommended that the model process be used to help establish an appropriate one for their initiative. Not all steps in the model process need to be performed at the level of detail indicated in the outlines below. The degree of detail and the amount of work required to complete some of these steps will vary widely, depending upon the situation.

It is important to understand that the process being presented here is assumed to be conducted only as a part of a broader, strategic-level safety management process. The details of that process, and its relation to this one, may be found in a companion guide. (The companion guide is a work in progress at this writing. When it is available, it will be posted online at http://transportation1.org/safetyplan.)

Overview of the Model Process

The process (see Exhibit VI-1, above) must be started at top levels in the lead agency's organization. This would, for example, include the CEO, DOT secretary, or chief engineer, as appropriate. Here, decisions will have been made to focus the agency's attention and resources on specific safety problems based upon the particular conditions and characteristics of the organization's roadway system. This is usually, but not always, documented as a result of the strategic-level process mentioned above. It often is publicized in the form of a "highway safety plan." Examples of what states produce include Wisconsin DOT's Strategic Highway Safety Plan (see Appendix A) and Iowa's Safety Plan (available at http://www.iowasms.org/toolbox.htm).

Once a "high-level" decision has been made to proceed with a particular emphasis area, the first step is to describe, in as much detail as possible, the problem that has been identified in the high-level analysis. The additional detail helps confirm to management that the problem identified in the strategic-level analysis is real and significant and that it is possible to do something about it. The added detail that this step provides to the understanding of the problem will also play an important part in identifying alternative approaches for dealing with it.

Step 1 should produce endorsement and commitments from management to proceed, at least through a planning process. With such an endorsement, it is then necessary to identify the stakeholders and define their role in the effort (Step 2). It is important at this step to identify a range of participants in the process who will be able to help formulate a comprehensive approach to the problem. The group will want to consider how it can draw upon potential actions directed at

- Driver behavior (legislation, enforcement, education, and licensing),
- Engineering,

- Emergency medical systems, and
- System management.

With the establishment of a working group, it is then possible to finalize an understanding of the nature and limitations of what needs to be done in the form of a set of program policies, guidelines, and specifications (Steps 3 and 4). An important aspect of this is establishing targets for crash reduction in the particular emphasis area (Step 3). Identifying stakeholders, defining their roles, and forming guidelines and policies are all elements of what is often referred to as "chartering the team." In many cases, and in particular where only one or two agencies are to be involved and the issues are not complex, it may be possible to complete Steps 1 through 4 concurrently.

Having received management endorsement and chartered a project team—the foundation for the work—it is now possible to proceed with project planning. The first step in this phase (Step 5 in the overall process) is to identify alternative strategies for addressing the safety problems that have been identified while remaining faithful to the conditions established in Steps 2 through 4.

With the alternative strategies sufficiently defined, they must be evaluated against one another (Step 6) and as groups of compatible strategies (i.e., a total program). The results of the evaluation will form the recommended plan. The plan is normally submitted to the appropriate levels of management for review and input, resulting ultimately in a decision on whether and how to proceed (Step 7). Once the working group has been given approval to proceed, along with any further guidelines that may have come from management, the group can develop a detailed plan of action (Step 8). This is sometimes referred to as an "implementation" or "business" plan.

Plan implementation is covered in Steps 9 and 10. There often are underlying activities that must take place prior to implementing the action plan to form a foundation for what needs to be done (Step 9). This usually involves creating the organizational, operational, and physical infrastructure needed to succeed. The major step (Step 10) in this process involves doing what was planned. This step will in most cases require the greatest resource commitment of the agency. An important aspect of implementation involves maintaining appropriate records of costs and effectiveness to allow the plan to be evaluated after-the-fact.

Evaluating the program, after it is underway, is an important activity that is often overlooked. Management has the right to require information about costs, resources, and effectiveness. It is also likely that management will request that the development team provide recommendations about whether the program should be continued and, if so, what revisions should be made. Note that management will be deciding on the future for any single emphasis area in the context of the entire range of possible uses of the agency's resources. Step 11 involves activities that will give the desired information to management for each emphasis area.

To summarize, the implementation of a program of strategies for an emphasis area can be characterized as an 11-step process. The steps in the process correspond closely to a 4-phase approach commonly followed by many transportation agencies:

- Endorsement and chartering of the team and project (Steps 1 through 4),
- Project planning (Steps 5 through 8),
- Plan implementation (Steps 9 and 10), and
- Plan evaluation (Step 11).

Details about each step follow. The Web-based version of this description is accompanied by a set of supplementary material to enhance and illustrate the points.

The model process is intended to provide a framework for those who need it. It is not intended to be a how-to manual. There are other documents that provide extensive detail regarding how to conduct this type of process. Some general ones are covered in Appendix B and Appendix C. Others, which relate to specific aspects of the process, are referenced within the specific sections to which they apply.

Implementation Step 1: Identify and Define the Problem

General Description

Program development begins with gathering data and creating and analyzing information. The implementation process being described in this guide is one that will be done in the context of a larger strategic process. It is expected that this guide will be used when the strategic process, or a project-level analysis, has identified a potentially significant problem in this emphasis area.

Data analyses done at the strategic level normally are done with a limited amount of detail. They are usually the top layer in a "drill-down" process. Therefore, while those previous analyses should be reviewed and used as appropriate, it will often be the case that further studies are needed to completely define the issues.

It is also often the case that a core technical working group will have been formed by the lead agency to direct and carry out the process. This group can conduct the analyses required in this step, but should seek, as soon as possible, to involve any other stakeholders who may desire to provide input to this process. Step 2 deals further with the organization of the working group.

The objectives of this first step are as follows:

1. Confirm that a problem exists in this emphasis area.
2. Detail the characteristics of the problem to allow identification of likely approaches for eliminating or reducing it.
3. Confirm with management, given the new information, that the planning and implementation process should proceed.

The objectives will entail locating the best available data and analyzing them to highlight either geographic concentrations of the problem or over-representation of the problem within the population being studied.

Identification of existing problems is *a responsive approach*. This can be complemented by a *proactive approach* that seeks to identify potentially hazardous conditions or populations.

For the responsive type of analyses, one generally begins with basic crash records that are maintained by agencies within the jurisdiction. This is usually combined, where feasible, with other safety data maintained by one or more agencies. The other data could include

- Roadway inventory,
- Driver records (enforcement, licensing, courts), or
- Emergency medical service and trauma center data.

To have the desired level of impact on highway safety, it is important to consider the highway system as a whole. Where multiple jurisdictions are responsible for various parts of the system, they should all be included in the analysis, wherever possible. The best example of this is a state plan for highway safety that includes consideration of the extensive mileage administered by local agencies. To accomplish problem identification in this manner will require a cooperative, coordinated process. For further discussion on the problem identification process, see Appendix D and the further references contained therein.

In some cases, very limited data are available for a portion of the roads in the jurisdiction. This can occur for a local road maintained by a state or with a local agency that has very limited resources for maintaining major databases. Lack of data is a serious limitation to this process, but must be dealt with. It may be that for a specific study, special data collection efforts can be included as part of the project funding. While crash records may be maintained for most of the roads in the system, the level of detail, such as good location information, may be quite limited. It is useful to draw upon local knowledge to supplement data, including

- Local law enforcement,
- State district and maintenance engineers,
- Local engineering staff, and
- Local residents and road users.

These sources of information may provide useful insights for identifying hazardous locations. In addition, local transportation agencies may be able to provide supplementary data from their archives. Finally, some of the proactive approaches mentioned below may be used where good records are not available.

Maximum effectiveness often calls for going beyond data in the files to include special supplemental data collected on crashes, behavioral data, site inventories, and citizen input. Analyses should reflect the use of statistical methods that are currently recognized as valid within the profession.

Proactive elements could include

- Changes to policies, design guides, design criteria, and specifications based upon research and experience;
- Retrofitting existing sites or highway elements to conform to updated criteria (perhaps with an appropriate priority scheme);
- Taking advantage of lessons learned from previous projects;
- Road safety audits, including on-site visits;
- Safety management based on roadway inventories;
- Input from police officers and road users; and
- Input from experts through such programs as the NHTSA traffic records assessment team.

The result of this step is normally a report that includes tables and graphs that clearly demonstrate the types of problems and detail some of their key characteristics. Such reports should be presented in a manner to allow top management to quickly grasp the key findings and help them decide which of the emphasis areas should be pursued further, and at what level of funding. However, the report must also document the detailed work that has been done, so that those who do the later stages of work will have the necessary background.

Specific Elements

1. Define the scope of the analysis
    - 1.1. All crashes in the entire jurisdiction
    - 1.2. A subset of crash types (whose characteristics suggest they are treatable, using strategies from the emphasis area)
    - 1.3. A portion of the jurisdiction
    - 1.4. A portion of the population (whose attributes suggest they are treatable using strategies from the emphasis area)
2. Define safety measures to be used for responsive analyses
    - 2.1. Crash measures
        - 2.1.1. Frequency (all crashes or by crash type)
        - 2.1.2. Measures of exposure
        - 2.1.3. Decide on role of frequency versus rates
    - 2.2. Behavioral measures
        - 2.2.1. Conflicts
        - 2.2.2. Erratic maneuvers
        - 2.2.3. Illegal maneuvers
        - 2.2.4. Aggressive actions
        - 2.2.5. Speed
    - 2.3. Other measures
        - 2.3.1. Citizen complaints
        - 2.3.2. Marks or damage on roadway and appurtenances, as well as crash debris
3. Define measures for proactive analyses
    - 3.1. Comparison with updated and changed policies, design guides, design criteria, and specifications
    - 3.2. Conditions related to lessons learned from previous projects
    - 3.3. Hazard indices or risk analyses calculated using data from roadway inventories to input to risk-based models
    - 3.4. Input from police officers and road users
4. Collect data
    - 4.1. Data on record (e.g., crash records, roadway inventory, medical data, driver-licensing data, citations, other)
    - 4.2. Field data (e.g., supplementary crash and inventory data, behavioral observations, operational data)
    - 4.3. Use of road safety audits, or adaptations
5. Analyze data
    - 5.1. Data plots (charts, tables, and maps) to identify possible patterns, and concentrations (See Appendixes Y, Z and AA for examples of what some states are doing)

   5.2. Statistical analysis (high-hazard locations, over-representation of contributing circumstances, crash types, conditions, and populations)
   5.3. Use expertise, through road safety audits or program assessment teams
   5.4. Focus upon key attributes for which action is feasible:
      5.4.1. Factors potentially contributing to the problems
      5.4.2. Specific populations contributing to, and affected by, the problems
      5.4.3. Those parts of the system contributing to a large portion of the problem

6. Report results and receive approval to pursue solutions to identified problems (a*pprovals being sought here are primarily a confirmation of the need to proceed and likely levels of resources required*)
   6.1. Sort problems by type
      6.1.1. Portion of the total problem
      6.1.2. Vehicle, highway/environment, enforcement, education, other driver actions, emergency medical system, legislation, and system management
      6.1.3. According to applicable funding programs
      6.1.4. According to political jurisdictions
   6.2. Preliminary listing of the types of strategies that might be applicable
   6.3. Order-of-magnitude estimates of time and cost to prepare implementation plan
   6.4. Listing of agencies that should be involved, and their potential roles (including an outline of the organizational framework intended for the working group). Go to Step 2 for more on this.

Implementation Step 2: Recruit Appropriate Participants for the Program

General Description

A critical early step in the implementation process is to engage all the stakeholders that may be encompassed within the scope of the planned program. The stakeholders may be from outside agencies (e.g., state patrol, county governments, or citizen groups). One criterion for participation is if the agency or individual will help ensure a comprehensive view of the problem and potential strategies for its resolution. If there is an existing structure (e.g., a State Safety Management System Committee) of stakeholders for conducting strategic planning, it is important to relate to this, and build on it, for addressing the detailed considerations of the particular emphasis area.

There may be some situations within the emphasis area for which no other stakeholders may be involved other than the lead agency and the road users. However, in most cases, careful consideration of the issues will reveal a number of potential stakeholders to possibly be involved. Furthermore, it is usually the case that a potential program will proceed better in the organizational and institutional setting if a high-level "champion" is found in the lead agency to support the effort and act as a key liaison with other stakeholders.

Stakeholders should already have been identified in the previous step, at least at a level to allow decision makers to know whose cooperation is needed, and what their potential level of involvement might be. During this step, the lead agency should contact the key individuals in each of the external agencies to elicit their participation and cooperation. This will require identifying the right office or organizational unit, and the appropriate people in each case. It will include providing them with a brief overview document and outlining for them the type of involvement envisioned. This may typically involve developing interagency agreements. The participation and cooperation of each agency should be secured to ensure program success.

Lists of appropriate candidates for the stakeholder groups are recorded in Appendix K. In addition, reference may be made to the NHTSA document at http://www.nhtsa.dot.gov/safecommunities/SAFE%20COMM%20Html/index.html, which provides guidance on building coalitions.

Specific Elements

1. Identify internal "champions" for the program
2. Identify the suitable contact in each of the agencies or private organizations who is appropriate to participate in the program
3. Develop a brief document that helps sell the program and the contact's role in it by
    - 3.1. Defining the problem
    - 3.2. Outlining possible solutions
    - 3.3. Aligning the agency or group mission by resolving the problem
    - 3.4. Emphasizing the importance the agency has to the success of the effort

   3.5. Outlining the organizational framework for the working group and other stakeholders cooperating on this effort
   3.6. Outlining the rest of the process in which agency staff or group members are being asked to participate
   3.7. Outlining the nature of commitments desired from the agency or group for the program
   3.8. Establishing program management responsibilities, including communication protocols, agency roles, and responsibilities
   3.9. Listing the purpose for an initial meeting
4. Meet with the appropriate representative
   4.1. Identify the key individual(s) in the agency or group whose approval is needed to get the desired cooperation
   4.2. Clarify any questions or concepts
   4.3. Outline the next steps to get the agency or group onboard and participating
5. Establish an organizational framework for the group
   5.1. Roles
   5.2. Responsibilities

Implementation Step 3: Establish Crash Reduction Goals

General Description

The AASHTO Strategic Highway Safety Plan established a national goal of saving 5,000 to 7,000 lives annually by the year 2003 to 2005. Some states have established statewide goals for the reduction of fatalities or crashes of a certain degree of severity. Establishing an explicit goal for crash reduction can place an agency "on the spot," but it usually provides an impetus to action and builds a support for funding programs for its achievement. Therefore, it is desirable to establish, within each emphasis area, one or more crash reduction targets.

These may be dictated by strategic-level planning for the agency, or it may be left to the stakeholders to determine. (The summary of the Wisconsin DOT Highway Safety Plan in Appendix A has more information.) For example, Pennsylvania adopted a goal of 10 percent reduction in fatalities by 2002,[1] while California established a goal of 40 percent reduction in fatalities and 15 percent reduction in injury crashes, as well as a 10 percent reduction in work zone crashes, in 1 year.[2] At the municipal level, Toledo, Ohio, is cited by the U.S. Conference of Mayors as having an exemplary program. This included establishing specific crash reduction goals (http://www.usmayors.org/uscm/uscm_projects_services/health/traffic/best_traffic_initiative_toledo.htm). When working within an emphasis area, it may be desirable to specify certain types of crashes, as well as the severity level, being targeted.

There are a few key considerations for establishing a quantitative goal. The stakeholders should achieve consensus on this issue. The goal should be challenging, but achievable. Its feasibility depends in part on available funding, the timeframe in which the goal is to be achieved, the degree of complexity of the program, and the degree of controversy the program may experience. To a certain extent, the quantification of the goal will be an iterative process. If the effort is directed at a particular location, then this becomes a relatively straightforward action.

Specific Elements

1. Identify the type of crashes to be targeted
    - 1.1. Subset of all crash types
    - 1.2. Level of severity
2. Identify existing statewide or other potentially related crash reduction goals
3. Conduct a process with stakeholders to arrive at a consensus on a crash reduction goal
    - 3.1. Identify key considerations
    - 3.2. Identify past goals used in the jurisdiction
    - 3.3. Identify what other jurisdictions are using as crash reduction goals
    - 3.4. Use consensus-seeking methods, as needed

[1] Draft State Highway Safety Plan, State of Pennsylvania, July 22, 1999
[2] Operations Program Business Plan, FY 1999/2000, State of California, Caltrans, July 1999

Implementation Step 4: Develop Program Policies, Guidelines, and Specifications

General Description

A foundation and framework are needed for solving the identified safety problems. The implementation process will need to be guided and evaluated according to a set of goals, objectives, and related performance measures. These will formalize what the intended result is and how success will be measured. The overlying crash reduction goal, established in Step 3, will provide the context for the more specific goals established in this step. The goals, objectives, and performance measures will be used much later to evaluate what is implemented. Therefore, they should be jointly outlined at this point and agreed to by all program stakeholders. It is important to recognize that evaluating any actions is an important part of the process. Even though evaluation is not finished until some time after the strategies have been implemented, it begins at this step.

The elements of this step may be simpler for a specific project or location than for a comprehensive program. However, even in the simpler case, policies, guidelines, and specifications are usually needed. Furthermore, some programs or projects may require that some guidelines or specifications be in the form of limits on directions taken and types of strategies considered acceptable.

Specific Elements

1. Identify high-level policy actions required and implement them (legislative and administrative)
2. Develop goals, objectives, and performance measures to guide the program and use for assessing its effect
    - 2.1. Hold joint meetings of stakeholders
    - 2.2. Use consensus-seeking methods
    - 2.3. Carefully define terms and measures
    - 2.4. Develop report documenting results and validate them
3. Identify specifications or constraints to be used throughout the project
    - 3.1. Budget constraints
    - 3.2. Time constraints
    - 3.3. Personnel training
    - 3.4. Capacity to install or construct
    - 3.5. Types of strategies not to be considered or that must be included
    - 3.6. Other

Implementation Step 5: Develop Alternative Approaches to Addressing the Problem

General Description

Having defined the problem and established a foundation, the next step is to find ways to address the identified problems. If the problem identification stage has been done effectively (see Appendix D for further details on identifying road safety problems), the characteristics of the problems should suggest one or more alternative ways for dealing with the problem. It is important that a full range of options be considered, drawing from areas dealing with enforcement, engineering, education, emergency medical services, and system management actions.

Alternative strategies should be sought for both location-specific and systemic problems that have been identified. Location-specific strategies should pertain equally well to addressing high-hazard locations and to solving safety problems identified within projects that are being studied for reasons other than safety.

Where site-specific strategies are being considered, visits to selected sites may be in order if detailed data and pictures are not available. In some cases, the emphasis area guides will provide tables that help connect the attributes of the problem with one or more appropriate strategies to use as countermeasures.

Strategies should also be considered for application on a systemic basis. Examples include

1. Low-cost improvements targeted at problems that have been identified as significant in the overall highway safety picture, but not concentrated in a given location.

2. Action focused upon a specific driver population, but carried out throughout the jurisdiction.

3. Response to a change in policy, including modified design standards.

4. Response to a change in law, such as adoption of a new definition for DUI.

In some cases, a strategy may be considered that is relatively untried or is an innovative variation from past approaches to treatment of a similar problem. Special care is needed to ensure that such strategies are found to be sound enough to implement on a wide-scale basis. Rather than ignoring this type of candidate strategy in favor of the more "tried-and-proven" approaches, consideration should be given to including a pilot-test component to the strategy.

The primary purpose of this guide is to provide a set of strategies to consider for eliminating or lessening the particular road safety problem upon which the user is focusing. As pointed out in the first step of this process, the identification of the problem, and the selection of strategies, is a complex step that will be different for each case. Therefore, it is not feasible to provide a "formula" to follow. However, guidelines are available. There are a number of texts to which the reader can refer. Some of these are listed in Appendix B and Appendix D.

In addition, the tables referenced in Appendix G provide examples for linking identified problems with candidate strategies.

The second part of this step is to assemble sets of strategies into alternative "program packages." Some strategies are complementary to others, while some are more effective when combined with others. In addition, some strategies are mutually exclusive. Finally, strategies may be needed to address roads across multiple jurisdictions. For instance, a package of strategies may need to address both the state and local highway system to have the desired level of impact. The result of this part of the activity will be a set of alternative "program packages" for the emphasis area.

It may be desirable to prepare a technical memorandum at the end of this step. It would document the results, both for input into the next step and for internal reviews. The latter is likely to occur, since this is the point at which specific actions are being seriously considered.

Specific Elements

1. Review problem characteristics and compare them with individual strategies, considering both their objectives and their attributes
    - 1.1. Road-user behavior (law enforcement, licensing, adjudication)
    - 1.2. Engineering
    - 1.3. Emergency medical services
    - 1.4. System management elements
2. Select individual strategies that do the following:
    - 2.1. Address the problem
    - 2.2. Are within the policies and constraints established
    - 2.3. Are likely to help achieve the goals and objectives established for the program
3. Assemble individual strategies into alternative program packages expected to optimize achievement of goals and objectives
    - 3.1. Cumulative effect to achieve crash reduction goal
    - 3.2. Eliminate strategies that can be identified as inappropriate, or likely to be ineffective, even at this early stage of planning
4. Summarize the plan in a technical memorandum, describing attributes of individual strategies, how they will be combined, and why they are likely to meet the established goals and objectives

Implementation Step 6: Evaluate Alternatives and Select a Plan

General Description

This step is needed to arrive at a logical basis for prioritizing and selecting among the alternative strategies or program packages that have been developed. There are several activities that need to be performed. One proposed list is shown in Appendix P.

The process involves making estimates for each of the established performance measures for the program and comparing them, both individually and in total. To do this in a quantitative manner requires some basis for estimating the effectiveness of each strategy. Where solid evidence has been found on effectiveness, it has been presented for each strategy in the guide. In some cases, agencies have a set of crash reduction factors that are used to arrive at effectiveness estimates. Where a high degree of uncertainty exists, it is wise to use sensitivity analyses to test the validity of any conclusions that may be made regarding which is the best strategy or set of strategies to use. Further discussion of this may be found in Appendix O.

Cost-benefit and cost-effectiveness analyses are usually used to help identify inefficient or inappropriate strategies, as well as to establish priorities. For further definition of the two terms, see Appendix Q. For a comparison of the two techniques, see Appendix S. Aspects of feasibility, other than economic, must also be considered at this point. An excellent set of references is provided within online benefit-cost guides:

- One is under development at the following site, maintained by the American Society of Civil Engineers: http://ceenve.calpoly.edu/sullivan/cutep/cutep_bc_outline_main.htm

- The other is *Guide to Benefit-Cost Analysis in Transport Canada*, September 1994, http://www.tc.gc.ca/finance/bca/en/TOC_e.htm. An overall summary of this document is given in Appendix V.

In some cases, a strategy or program may look promising, but no evidence may be available as to its likely effectiveness. This would be especially true for innovative methods or use of emerging technologies. In such cases, it may be advisable to plan a pilot study to arrive at a minimum level of confidence in its effectiveness, before large-scale investment is made or a large segment of the public is involved in something untested.

It is at this stage of detailed analysis that the crash reduction goals, set in Step 3, may be revisited, with the possibility of modification.

It is important that this step be conducted with the full participation of the stakeholders. If the previous steps were followed, the working group will have the appropriate representation. Technical assistance from more than one discipline may be necessary to go through more complex issues. Group consensus will be important on areas such as estimates of effectiveness, as well as the rating and ranking of alternatives. Techniques are available to assist in arriving at consensus. For example, see the following Web site for an overview: http://web.mit.edu/publicdisputes/practices/cbh_ch1.html.

Specific Elements

1. Assess feasibility
    - 1.1. Human resources
    - 1.2. Special constraints
    - 1.3. Legislative requirements
    - 1.4. Other
    - 1.5. This is often done in a qualitative way, to narrow the list of choices to be studied in more detail (see, for example, Appendix BB)
2. Estimate values for each of the performance measures for each strategy and plan
    - 2.1. Estimate costs and impacts
        - 2.1.1. Consider guidelines provided in the detailed description of strategies in this material
        - 2.1.2. Adjust as necessary to reflect local knowledge or practice
        - 2.1.3. Where a plan or program is being considered that includes more than one strategy, combine individual estimates
    - 2.2. Prepare results for cost-benefit and/or cost-effectiveness analyses
    - 2.3. Summarize the estimates in both disaggregate (by individual strategy) and aggregate (total for the program) form
3. Conduct a cost-benefit and/or cost-effectiveness analysis to identify inefficient, as well as dominant, strategies and programs and to establish a priority for the alternatives
    - 3.1. Test for dominance (both lower cost and higher effectiveness than others)
    - 3.2. Estimate relative cost-benefit and/or cost-effectiveness
    - 3.3. Test productivity
4. Develop a report that documents the effort, summarizing the alternatives considered and presenting a preferred program, as devised by the working group (for suggestions on a report of a benefit-cost analysis, see Appendix U).
    - 4.1. Designed for high-level decision makers, as well as technical personnel who would be involved in the implementation
    - 4.2. Extensive use of graphics and layout techniques to facilitate understanding and capture interest
    - 4.3. Recommendations regarding meeting or altering the crash reduction goals established in Step 3.

Implementation Step 7: Submit Recommendations for Action by Top Management

General Description

The working group has completed the important planning tasks and must now submit the results and conclusions to those who will make the decision on whether to proceed further. Top management, at this step, will primarily be determining if an investment will be made in this area. As a result, the plan will not only be considered on the basis of its merits for solving the particular problems identified in this emphasis area (say, vis-à-vis other approaches that could be taken to deal with the specific problems identified), but also its relative value in relation to investments in other aspects of the road safety program.

This aspect of the process involves using the best available communication skills to adequately inform top management. The degree of effort and extent of use of media should be proportionate to the size and complexity of the problem being addressed, as well as the degree to which there is competition for funds.

The material that is submitted should receive careful review by those with knowledge in report design and layout. In addition, today’s technology allows for the development of automated presentations, using animation and multimedia in a cost-effective manner. Therefore, programs involving significant investments that are competing strongly for implementation resources should be backed by such supplementary means for communicating efficiently and effectively with top management.

Specific Elements

1. Submit recommendations for action by management
    - 1.1. “Go/no-go” decision
    - 1.2. Reconsideration of policies, guidelines, and specifications (see Step 3)
    - 1.3. Modification of the plan to accommodate any revisions to the program framework made by the decision makers
2. Working group to make presentations to decision makers and other groups, as needed and requested
3. Working group to provide technical assistance with the review of the plan, as requested
    - 3.1. Availability to answer questions and provide further detail
    - 3.2. Assistance in conducting formal assessments

Implementation Step 8: Develop a Plan of Action

General Description

At this stage, the working group will usually detail the program that has been selected for implementation. This step translates the program into an action plan, with all the details needed by both decision makers, who will have to commit to the investment of resources, and those charged with carrying it out. The effort involves defining resource requirements, organizational and institutional arrangements needed, schedules, etc. This is usually done in the form of a business plan, or plan of action. An example of a plan developed by a local community is shown in Appendix X.

An evaluation plan should be designed at this point. It is an important part of the plan. This is something that should be in place before Step 9 is finished. It is not acceptable to wait until after the program is completed to begin designing an evaluation of it. This is because data are needed about conditions before the program starts, to allow comparison with conditions during its operation and after its completion. It also should be designed at this point, to achieve consensus among the stakeholders on what constitutes "success." The evaluation is used to determine just how well things were carried out and what effect the program had. Knowing this helps maintain the validity of what is being done, encourages future support from management, and provides good intelligence on how to proceed after the program is completed. For further details on performing evaluations, see Appendix L, Appendix M, and Appendix W.

The plan of action should be developed jointly with the involvement of all desired participants in the program. It should be completed to the detail necessary to receive formal approval of each agency during the next step. The degree of detail and complexity required for this step will be a function of the size and scope of the program, as well as the number of independent agencies involved.

Specific Elements

1. Translation of the selected program into key resource requirements
    - 1.1. Agencies from which cooperation and coordination is required
    - 1.2. Funding
    - 1.3. Personnel
    - 1.4. Data and information
    - 1.5. Time
    - 1.6. Equipment
    - 1.7. Materials
    - 1.8. Training
    - 1.9. Legislation
2. Define organizational and institutional framework for implementing the program
    - 2.1. Include high-level oversight group
    - 2.2. Provide for involvement in planning at working levels
    - 2.3. Provide mechanisms for resolution of issues that may arise and disagreements that may occur
    - 2.4. Secure human and financial resources required

3. Detail a program evaluation plan
    3.1. Goals and objectives
    3.2. Process measures
    3.3. Performance measures
        3.3.1. Short-term, including surrogates, to allow early reporting of results
        3.3.2. Long-term
    3.4. Type of evaluation
    3.5. Data needed
    3.6. Personnel needed
    3.7. Budget and time estimates
4. Definition of tasks to conduct the work
    4.1. Develop diagram of tasks (e.g., PERT chart)
    4.2. Develop schedule (e.g., Gantt chart)
    4.3. For each task, define
        4.3.1. Inputs
        4.3.2. Outputs
        4.3.3. Resource requirements
        4.3.4. Agency roles
        4.3.5. Sequence and dependency of tasks
5. Develop detailed budget
    5.1. By task
    5.2. Separate by source and agency/office (i.e., cost center)
6. Produce program action plan, or business plan document

Implementation Step 9: Establish Foundations for Implementing the Program

General Description

Once approved, some "groundwork" is often necessary to establish a foundation for carrying out the selected program. This is somewhat similar to what was done in Step 4. It must now be done in greater detail and scope for the specific program being implemented. As in Step 4, specific policies and guidelines must be developed, organizational and institutional arrangements must be initiated, and an infrastructure must be created for the program. The business plan or action plan provides the basis (Step 7) for this. Once again, the degree of complexity required will vary with the scope and size of the program, as well as the number of agencies involved.

Specific Elements

1. Refine policies and guidelines (from Step 4)
2. Effect required legislation or regulations
3. Allocate budget
4. Reorganize implementation working group
5. Develop program infrastructure
    - 5.1. Facilities and equipment for program staff
    - 5.2. Information systems
    - 5.3. Communications
    - 5.4. Assignment of personnel
    - 5.5. Administrative systems (monitoring and reporting)
6. Set up program assessment system
    - 6.1. Define/refine/revise performance and process measures
    - 6.2. Establish data collection and reporting protocols
    - 6.3. Develop data collection and reporting instruments
    - 6.4. Measure baseline conditions

Implementation Step 10: Carry Out the Action Plan

General Description

Conditions have been established to allow the program to be started. The activities of implementation may be divided into activities associated with field preparation for whatever actions are planned and the actual field implementation of the plan. The activities can involve design and development of program actions, actual construction or installation of program elements, training, and the actual operation of the program. This step also includes monitoring for the purpose of maintaining control and carrying out mid- and post-program evaluation of the effort.

Specific Elements

1. Conduct detailed design of program elements
    - 1.1. Physical design elements
    - 1.2. PI&E materials
    - 1.3. Enforcement protocols
    - 1.4. Etc.
2. Conduct program training
3. Develop and acquire program materials
4. Develop and acquire program equipment
5. Conduct pilot tests of untested strategies, as needed
6. Program operation
    - 6.1. Conduct program "kickoff"
    - 6.2. Carry out monitoring and management of ongoing operation
        - 6.2.1 Periodic measurement (process and performance measures)
        - 6.2.2 Adjustments as required
    - 6.3. Perform interim and final reporting

Implementation Step 11: Assess and Transition the Program

General Description

The AASHTO Strategic Highway Safety Plan includes improvement in highway safety management. A key element of that is the conduct of properly designed program evaluations. The program evaluation will have been first designed in Step 8, which occurs prior to any field implementation. For details on designing an evaluation, please refer to Step 8. For an example of how the New Zealand Transport Authority takes this step as an important part of the process, see Appendix N.

The program will usually have a specified operational period. An evaluation of both the process and performance will have begun prior to the start of implementation. It may also continue during the course of the implementation, and it will be completed after the operational period of the program.

The overall effectiveness of the effort should be measured to determine if the investment was worthwhile and to guide top management on how to proceed into the post-program period. This often means that there is a need to quickly measure program effectiveness in order to provide a preliminary idea of the success or need for immediate modification. This will be particularly important early in development of the AASHTO Strategic Highway Safety Plan, as agencies learn what works best. Therefore, surrogates for safety impact may have to be used to arrive at early/interim conclusions. These usually include behavioral measures. This particular need for interim surrogate measures should be dealt with when the evaluation is designed, back in Step 8. However, a certain period, usually a minimum of a couple of years, will be required to properly measure the effectiveness and draw valid conclusions about programs designed to reduce highway fatalities when using direct safety performance measures.

The results of the work is usually reported back to those who authorized it and the stakeholders, as well as any others in management who will be involved in determining the future of the program. Decisions must be made on how to continue or expand the effort, if at all. If a program is to be continued or expanded (as in the case of a pilot study), the results of its assessment may suggest modifications. In some cases, a decision may be needed to remove what has been placed in the highway environment as part of the program because of a negative impact being measured. Even a “permanent” installation (e.g., rumble strips) requires a decision regarding investment for future maintenance if it is to continue to be effective.

Finally, the results of the evaluation using performance measures should be fed back into a knowledge base to improve future estimates of effectiveness.

Specific Elements

1. Analysis
    - 1.1. Summarize assessment data reported during the course of the program
    - 1.2. Analyze both process and performance measures (both quantitative and qualitative)

    1.3. Evaluate the degree to which goals and objectives were achieved (using performance measures)
    1.4. Estimate costs (especially vis-à-vis pre-implementation estimates)
    1.5. Document anecdotal material that may provide insight for improving future programs and implementation efforts
    1.6. Conduct and document debriefing sessions with persons involved in the program (including anecdotal evidence of effectiveness and recommended revisions)
2. Report results
3. Decide how to transition the program
    3.1. Stop
    3.2. Continue as is
    3.3. Continue with revisions
    3.4. Expand as is
    3.5. Expand with revisions
    3.6. Reverse some actions
4. Document data for creating or updating database of effectiveness estimates

SECTION VII

Key References

American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets.* Washington, D.C. 2001.

Bauer, K. M., and D. W. Harwood, *Statistical Models of At-Grade Intersection Accidents.* Report No. FHWA-RD-96-125, Federal Highway Administration. November, 1996.

Blackburn, R. R., and D. T. Gilbert, *NCHRP Synthesis of Highway Practice 219: Photographic Enforcement of Traffic Laws,* Transportation Research Board of the National Academies, 1995.

Box, P. C., "Major Road Accident Reduction by Illumination," *Transportation Research Record 1247,* Transportation Research Board of the National Academies, 1988.

Carstens, R. L., and R. Y. Woo, *Warrants for Rumble Strips on Rural Highways,* Report No. HR-235, Iowa Highway Research Board, June 1982.

City of Los Angeles, *Intersection Accident Reduction through Street Lighting,* OTS Project 127803, Bureau of Street Lighting, 1980.

De Waard, D., and T. Rooijers, "An Experimental Study to Evaluate the Effectiveness of Different Methods and Intensities of Law Enforcement on Driving Speed on Motorways," *Accident Analysis and Prevention,* Volume 126, Issue 6, 1994.

Dougherty, D. A., *Selective Traffic Enforcement Program Champaign—Interim Evaluation Report,* Illinois Department of Transportation, May 1977.

Downs, H. G., Jr., and D. W. Wallace, *NCHRP Report 254: Shoulder Geometrics and Use Guidelines,* Transportation Research Board of the National Academies, 1982.

Federal Highway Administration, *Collision Countermeasure System (CCS).* Brochure provided by Paul Pisano, October 1998.

Federal Highway Administration, *Manual on Uniform Traffic Control Devices (MUTCD),* Washington, D.C. 2000.

Federal Highway Administration, *Pedestrian & Bicycle Crash Analysis Tool.* TechBrief. Report No. FHWA-RD-00-095, June 2000.

Florida Department of Transportation, *Median Handbook,* January 1997 (contained in FHWA Access Management CD Library, Version 1.0, January 2000).

Gallagher, V. P., *New Directions in Roadway Lighting,* Report No. FHWA-TS-80-223, Illuminating Engineering Society, 1980.

Gattis, J. L., and S. T. Low, "Intersection Angle Geometry and the Driver's Field of View," *Transportation Research Record 1612,* Transportation Research Board of the National Academies, 1998.

Glennon, J. C., J. J. Valenta, B. A. Thorson, and J. A. Azzeh, *Technical Guidelines for Direct Access Control to Arterial Highways,* Report No. FHWA-RD-76-87, Federal Highway Administration. August, 1976.

Gluck, J., H. S. Levinson, and V. Stover, *NCHRP Report 420: Impacts of Access Management Techniques,* Transportation Research Board of the National Academies, 1999.

Hammer, J. B., and E. J. Tye, *Overhead Yellow-Red Flashing Beacons,* Report No. FHWA/CA/TE-87/01, Federal Highway Administration, 1987.

Hanna, J. T., T. E. Flynn, and W. L. Tyler, "Characteristics of Intersection Accidents in Rural Municipalities," *Transportation Research Record 601,* Transportation Research Board of the National Academies, 1976.

Hanscom, F. *Evaluation of the Prince William County Collision Countermeasure System,* Virginia Transportation Research Council, VTRC 01-CR5, 2001.

Harmelink, M. D., "Volume Warrants for Left-Turn Storage Lanes at Unsignalized Grade Intersections," *Highway Research Record 211,* Highway Research Board of the National Academies, 1967.

Harwood, D. W., *NCHRP Synthesis of Highway Practice 191: Use of Rumble Strips to Enhance Safety,* Transportation Research Board of the National Academies, 1993.

Harwood, D. W., K. M. Bauer, I. B. Potts, D. J. Torbic, K. R. Richard, E. R. Kohlman Rabbani, E. Hauer, and L. Elefteriadou, *Safety Effectiveness of Intersection Left- and Right-Turn Lanes,* Report No. FHWA-RD-02-089, Federal Highway Administration, 2002.

Harwood, D. W., F. M. Council, E. Hauer, W. E. Hughes, and A. Vogt, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways,* Report No. FHWA-RD-99-207, Federal Highway Administration, 2000.

Harwood, D. W., and C. J. Hoban, *Low-Cost Methods for Improving Traffic Operations on Two-Lane Roads,* Report No. FHWA-IP-87-2, Federal Highway Administration, 1987.

Harwood, D. W., J. M. Mason, R. E. Brydia, M. T. Pietrucha, and G. L. Gittings, *NCHRP Report 383: Intersection Sight Distance,* Transportation Research Board of the National Academies, 1996.

Harwood, D. W., M. T. Pietrucha, M. D. Wooldridge, R. E. Brydia, and K. Fitzpatrick, *NCHRP Report 375: Median Intersection Design,* Transportation Research Board of the National Academies, 1995.

Hingson, R. H., J. Howland, T. Schiavone, and M. Damiata, "The Massachusetts Saving Lives Program: Six Cities Widening the Focus from Drunk Driving to Speeding, Reckless Driving, and Failure to Wear Safety Belts," *Journal of Traffic Medicine,* Vol. 18, No. 3, 1990.

Hunter, W. H., J. C. Stutts, W. E. Pein, and C. L. Cox, *Pedestrian and Bicycle Crash Types of the Early 1990s,* Report No. FHWA-RD-95-163, Federal Highway Administration, 1996.

Illinois Division of Highways, *Accident Study Report 102: Rumbles Strips Used as a Traffic Control Device: An Engineering Analysis,* April 1, 1970.

Institute of Transportation Engineers, "Effectiveness of Median Storage and Acceleration Lanes for Left-Turning Vehicles," *ITE Journal,* Vol. 55, No. 3, 1985.

Institute of Transportation Engineers, *ITE Speed Zoning Guidelines,* ITE Committee 4M-25 Speed Zone Guidelines, Recommended Practice, Final Draft Version, undated, taken from: http://www.ibiblio.org/rdu/ite-szg.html.

Jacquemart, G., *NCHRP Synthesis of Highway Practice 264: Modern Roundabout Practice in the United States,* Transportation Research Board of the National Academies, 1998.

Johnson, K., "Aggressive Driving: One City's Solution," *Traffic Safety Journal,* Issue No. 4, National Safety Council, July 2000.

Joshua, S. C., and A. A. Saka., "Mitigation of Sight Distance Problem for Unprotected Left-Turning Traffic at Intersections," *Transportation Research Record 1356,* Transportation Research Board of the National Academies, 1992.

Kallberg, V. P., and S. Ranta, "Impacts of Urban Speed-Reducing Measures," *2nd International Symposium on Highway Geometric Design,* Proceedings, 2000.

Karr, A., "DOT Launches Campaign to Curb Drunk Driving Deaths," *Traffic Safety Journal,* Issue No. 3, National Safety Council, May 2000.

Kermit, M. L., and T. C. Hein, *Effect of Rumble Strips on Traffic Control and Behavior,* Proceedings, Highway Research Board of the National Academies, Vol. 41, 1962.

Knapp, K. K. "Traffic-Calming Basics," *Civil Engineering,* Vol. 70, No. 1, 2000.

Kuciemba, S. R., and J. A. Cirillo. *Safety Effectiveness of Highway Design Features, Volume V: Intersections,* Report No. FHWA-RD-91-048, Federal Highway Administration, November 1992.

Larsen, J. H., "Develop Your Own In-House Public Relations Program," *ITE Journal,* Vol. 61, No. 1, January 1991.

McCoy, P. T., U. R. Navarro, and W. E. Witt, "Guidelines for Offsetting Opposing Left-Turn Lanes on Four-Lane Divided Roadways," *Transportation Research Record 1356,* Transportation Research Board of the National Academies, 1992.

McCoy, P. T., E. J. Tripi, and J. A. Bonneson, *Guidelines for Realignment of Skewed Intersections: Final Report,* Nebraska Department of Roads, November 1994.

Moore, A. F., *Evaluation of Experimental Rumble Strips,* Report No. FHWA-LA-86-186, Louisiana Transportation Research Center, July 1987.

National Center for Bicycling and Walking: www.bikefed.org.

Neuman, T. R., *NCHRP Report 279: Intersection Channelization Design Guide,* Transportation Research Board of the National Academies, 1985.

Oei, H. L., "Automatic Speed Management in the Netherlands," *Transportation Research Record 1560,* Transportation Research Board of the National Academies, 1996.

Owens, R. D., "Effect of Rumble Strip at Rural Stop Locations on Traffic Operation," *Highway Research Record 170,* Highway Research Board of the National Academies, 1967.

Pant, P. D., Y. Park, and S. V. Neti, *Development of Guidelines for Installation of Intersection Control Beacons,* Report No. FHWA/OH-93/006, Federal Highway Administration, 1992.

Pedestrian and Bicycle Information Center: www.walkinginfo.org.

Persaud, B. N., R. A. Retting, P. Garder, and D. Lord, *Crash Reductions Following Installation of Roundabouts in the United States.* Insurance Institute for Highway Safety, 2000.

Persaud, B. N., R. A. Retting, P. E. Garder, and D. Lord, "Safety Effect of Roundabout Conversions in the United States: Empirical Bayes Observational Before-After Study," *Transportation Research Record 1751,* Transportation Research Board of the National Academies, 2001.

Pierowicz, J., E. Jocoy, M. Lloyd, A. Bittner, and B. Pirson, *Intersection Collision Avoidance Using ITS Countermeasures,* Task 9 final report, Veridian Engineering Report 8149-12, 2000.

Pigman, J. G., and M. M. Barclay, *Evaluation of Rumble Strip Design and Usage,* Report No. UKTRP-81-11, Kentucky Transportation Research Program, July 1981.

Pline, J. L., *NCHRP Synthesis of Highway Practice 225: Left-Turn Treatments at Intersections,* Transportation Research Board of the National Academies, 1996.

Pline, J. L., *Traffic Engineering Handbook,* Institute of Transportation Engineers, 1999.

Preston, H., and T. Schoenecker, *Bypass Lane Safety, Operations, and Design Study,* Report No. MN/RC–2000–22, Minnesota Department of Transportation, July 1999a.

Preston, H., and T. Schoenecker, *Safety Impacts of Street Lighting at Isolated Rural Intersections,* Report No. MN/RC–1999–17, Minnesota Department of Transportation, April 1999b.

Robinson, B. W., L. Rodegerdts, W. Scarborough, W. Kittelson, R. Troutbeck, W. Brilon, L. Bondzio, K. Courage, M. Kyte, J. Mason, A. Flannery, E. Myers, J. Bunker, and G. Jacquemart, *Roundabouts: An Informational Guide,* Report No. FHWA-RD-00-067, Federal Highway Administration, June 2000.

Sebastian, O. L., and R. S. Pusey, *Paved-Shoulder Left-Turn By-Pass Lanes: A Report on the Delaware Experience,* Delaware Department of Transportation, October 1982.

Snyder, M. B., and R. L. Knoblauch, *Pedestrian Safety: The Identification of Precipitating Factors and Possible Countermeasures,* Publication No. FH-11-7312, National Highway Traffic Safety Administration, 1971.

Staplin, L., K. Lococo, and S. Byington, *Older Driver Highway Design Handbook,* Report No. FHWA-RD-97-135, Federal Highway Administration, January 1998.

Sumner, R., and J. Shippey, *The Use of Rumble Areas to Alert Drivers,* TRRL Laboratory Report 800, Transport and Road Research Laboratory, Department of Environment, Department of Transport, Crowthorne, Berkshire, United Kingdom, 1977.

Taylor, R. W., *Grooved Rumble Strips as a Traffic Control Device in Pennsylvania,* M. S. Thesis, Pennsylvania State University, 1974.

TRB Special Report 254: Managing Speed: Review of Current Practice for Setting and Enforcing Speed Limits, Transportation Research Board of the National Academies, 1998.

Tyrrell, R. A., and C. W. Patton, *The Effectiveness of Educating Pedestrians About Their Own Nighttime Visibility,* Human Factors and Ergonomics Society 42nd Annual Meeting, Proceedings, 1998.

Virginia Department of Highways and Transportation, *An Evaluation of the Effectiveness of Rumble Strips,* Traffic and Safety Division Evaluation No. 81-5, April 1991.

Waller, P. F., *Transportation Quarterly,* Vol. 56, No. 3, "Speed Limits: How Should They Be Determined?" 2002.

Williams, J., B. Burgess, P. Moe, and B. Wilkinson, *Implementing Bicycle Improvements at the Local Level.* Report No. FHWA-RD-98-105, Federal Highway Administration, 1998.

Zaidel, D., A. S. Hakkert, and R. Barkan, "Rumble Strips and Paint Stripes at a Rural Intersection," *Transportation Research Record 1069,* Transportation Research Board of the National Academies, 1986.

Zegeer, C. V., and J. A. Deacon, *TRB State-of-the-Art Report 6: Effect of Lane Width, Shoulder Width, and Shoulder Type on Highway Safety,* Transportation Research Board of the National Academies, 1987.

Section VIII

Glossary

Acronym or Term	Meaning	Comments
3R	Rehabilitation, Resurfacing, and Restoration	Refers to type of project that is intended to be less comprehensive than complete reconstruction
AAA	American Automobile Association	
AAAM	Association for the Advancement of Automotive Medicine	
AAMVA	American Association of Motor Vehicle Administrators	
AASHTO	American Association of State Highway and Transportation Officials	
ADAT	Aggressive Driving Apprehension Team	Washington State Patrol
ADT	Average Daily Traffic	
AG	Aggressive Driving	
AMA	American Medical Association	
AMF (or CMF)	Accident Modification Factor	Also may be referred to as Crash Modification Factor
ARTBA	American Road and Transportation Builders Association	
ASCE	American Society of Civil Engineers	
AWS	Accident Warning System	
B/C	Benefit-Cost Ratio	
BCT	Breakaway Cable Terminal	End treatment for guardrail
CAE	Computer Aided Engineering	
CCS	Collision Countermeasure System	
CDL	Commercial Driver's License	
CHSIM	Comprehensive Highway Safety Improvement Model	Recently changed name to *The SafetyAnalyst*
CSD	Context-Sensitive Design	
DDC-ADD	Defensive Driving Course—Attitudinal Dynamics of Driving	

Acronym or Term	Meaning	Comments
DDSS	Design Decision Support System	
DES	Detailed Engineering Studies	
DMV	Department of Motor Vehicles	
DOT	Department of Transportation	
DUI/DWI	Driving Under the Influence (of alcohol or drugs)/Driving While Impaired	
DUS	Driving Under Suspension (of driver's license)	
DWR	Driving While Revoked	
DWS	Driving While Suspended	
EM	Electronic Monitoring	
FARS	Fatality Analysis Reporting System	Formerly referred to as Fatal Accident Reporting System
FHWA	Federal Highway Administration	Division of the U.S. Department of Transportation
F+I	Fatal Plus Injury (crash)	
GHSA	Governors Highway Safety Association	Formerly NAGHSR (National Association of Governors' Highway Safety Representatives)
Green Book	AASHTO Policy on Geometric Design of Highways	
H.A.D.	Halt Aggressive Driving	Lubbock, Texas
HAL	High Accident Location	
HCM	Highway Capacity Manual	TRB publication
HES	Hazard Elimination Study	
HO	Head On (accident)	
HOS	Hours of Service	For commercial vehicle drivers
HRR	Highway Research Record	TRB publication
HSIS	Highway Safety Information System	
HSM	Highway Safety Manual	
IES	Illumination Engineering Society	
IHSDM	Interactive Highway Safety Design Model	
IID	Ignition Interlock Device	
ISD	Intersection Sight Distance	

Acronym or Term	Meaning	Comments
ITE	Institute of Transportation Engineers	
LCCA	Life Cycle Cost Analysis	
MAB	Medical Advisory Board	State-level organization
MADD	Mothers Against Drunk Driving	
MUTCD	Manual on Uniform Traffic Control Devices	FHWA publication
NCHRP	National Cooperative Highway Research Program	
NHI	National Highway Institute	FHWA training office
NHTSA	National Highway Traffic Safety Administration	Division of the U.S. Department of Transportation
NSC	National Safety Council	
NTSB	National Transportation Safety Board	
NYSTA	New York State Thruway Authority	
PCR	Police Crash Report	
PDO	Property Damage Only (accident)	
PI&E	Public Information & Education	
RDG	Roadside Design Guide	AASHTO publication
RID	Remove Intoxicated Drivers	Citizen group
ROR	Run-Off-Road (accident)	
ROW	Right-of-Way	
RPM	Raised Pavement Marker	
RSA	Road Safety Audit	
RSPM	Raised Snowplowable Pavement Marker	
SADD	Students Against Destructive Decisions	
SBPD	Santa Barbara Police Department (California)	
SHSP	Strategic Highway Safety Plan	
SKARP	Skid Accident Reduction Program	
SPF	Safety Performance Function	
SSD	Stopping Sight Distance	
SUV	Sports Utility Vehicle	
SV	Single Vehicle (accident)	

Acronym or Term	Meaning	Comments
TCD	Traffic Control Device	
TRB	Transportation Research Board	
TRR	Transportation Research Record	TRB publication
TRRL	Transport and Road Research Laboratory	United Kingdom organization
TSIMS	Transportation Safety Information Management System	Developed by AASHTO
TTI	Texas Transportation Institute	
TWLTL	Two-Way, Left-Turn Lane	
U/S/R	Unlicensed/Suspended/Revoked	Drivers without licenses, or whose licenses have been suspended or revoked
UVC	Uniform Vehicle Code	Model national traffic law
WSP	Washington State Patrol	

See also: Glossary of Transportation Terms online
http://transweb.sjsu.edu/comglos2.htm#P

Appendixes

The following appendixes are not published in this report. However, they are available online at http://transportation1.org/safetyplan.

1 Evaluation of the Prince William County Collision Countermeasure System
2 Intersection Collision Avoidance Using ITS Countermeasures
3 Index of Strategies vs. Related Crash Factors
4 Candidate Types of Stakeholders for Involvement in Planning and Implementing Programs to Mitigate Crashes at Unsignalized Intersections

A Wisconsin Department of Transportation 2001 Strategic Highway Safety Plan
B Resources for the Planning and Implementation of Highway Safety Programs
C South African Road Safety Manual
D Comments on Problem Definition
E Issues Associated with Use of Safety Information in Highway Design: Role of Safety in Decision Making
F Comprehensive Highway Safety Improvement Model
G Table Relating Candidate Strategies to Safety Data Elements
H What is a Road Safety Audit?
I Illustration of Regression to the Mean
J Fault Tree Analysis
K Lists of Potential Stakeholders
L Conducting an Evaluation
M Designs for a Program Evaluation
N Joint Crash Reduction Programme: Outcome Monitoring
O Estimating the Effectiveness of a Program During the Planning Stages
P Key Activities for Evaluating Alternative Program
Q Definitions of Cost-Benefit and Cost-Effectiveness
R FHWA Policy on Life Cycle Costing
S Comparisons of Benefit-Cost and Cost-Effectiveness Analysis
T Issues in Cost-Benefit and Cost-Effectiveness Analyses
U Transport Canada Recommended Structure for a Benefit-Cost Analysis Report
V Overall Summary of Benefit-Cost Analysis Guide from Transport Canada
W Program Evaluation—Its Purpose and Nature
X Traffic Safety Plan for a Small Department
Y Sample District-Level Crash Statistical Summary
Z Sample Intersection Crash Summaries
AA Sample Intersection Collision Diagram
BB Example Application of the Unsignalized Intersection Guide

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation