VOLUME 4

NCHRP

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

REPORT 500

Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

Volume 4: A Guide for Addressing Head-On Collisions

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Volume 4: A Guide for Addressing Head-On Collisions

Timothy R. Neuman
CH2M HILL
Chicago, IL

Ronald Pfefer
Maron Engineering, Ltd.
Zikhron Yaacov, Israel

Kevin L. Slack
Kelly Kennedy Hardy
CH2M HILL
Herndon, VA

Hugh McGee
Leanne Prothe
Kimberly Eccles
BMI
Vienna, VA

Forrest Council
BMI
Chapel Hill, NC

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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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 fourth 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 head-on crashes on two-lane roads. 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 fourth 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

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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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Tony Kane

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Alberto Gutier

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Bill Anderson

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Consultant
Terry Witkowski

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Stephen Blake

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Mike Bradshaw

Delaware State Police
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Durham Police Department
James R. Cleary
Teen Ennis

Federal Highway Administration
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Joe Bared
Joshua Grzegorzewski
Michael Halladay
Carl Hayden
Hari Kalla
Martha Kapitanov
Nak Joo Kim
Kristine Leiphart
Liana Liu
Leonard Meczkowski
Richard Powers
Harry W. Taylor

Federal Highway Administration—Eastern Federal Lands
Ken Atkins

Federal Highway Administration—Midwest Resource Center
Patrick Hasson

Federal Highway Administration—Southern Resource Center
K. Lynn Berry
Mary Jane Daluge
Julian Frank
Eric Worrell

Florida Department of Transportation
Brian Blanchard
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Richard Retting

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Dave Little
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Kansas Department of Transportation
Jim Brewer
Ron Seitz

Kentucky Department of Highways
Simon Cornett

Lee County, Florida, Sheriff's Office
Dennis Brooks
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Lockhart, Texas, Police Department
Charles L. Bethel

Maine Department of Transportation
Gerry Audibert
Robert LaRoche

Maryland Motor Vehicle Administration
Jane Valenzia

Maryland State Highway Administration
Ken Briggs
Curt Childress
Manu Shah

Michigan Department of Transportation
Kurt Kunde
Andy Zeigler

Michigan Governor's Office
Chad Canfield

Michigan State Police Department
Mike Nof

Mid-America Research
John Lacey

Minnesota Department of Public Safety
Joseph Bowler
Scott Bradley

Minnesota Department of Transportation
Ron Erickson
Loren Hill

Mississippi Department of Transportation
John B. Pickering
John Reese
Jim Willis

Missouri Department of Transportation
Steve McDonald

National Association of County Engineers
Tony Giancolo

National Highway Traffic Safety Administration
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New York State Department of Transportation
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Robert Limoges
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Ohio Department of Transportation
Larry Sutherland

Oregon Department of Transportation
Jeff Greiner
Chris Monsere
Vivian Payne

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Kathy Hoffman

Santa Barbara, California, Police Department/Traffic Safety
David Whitham

Scenic America
Meg Maguire

Smithville, Texas, Police Department
Lee Nusbaum

South Carolina Department of Transportation
William Bloom
Terecia Wilson

Texas Department of Transportation
Paul Frerich
Darren McDaniel

Texas Transportation Institute
Dean Iberson

Town of Chapel Hill, North Carolina
Kumar Neppalli

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John C. Milton

Washington State Patrol
John Batiste
Tim Quenzer

Westat
Neil Lerner

West Virginia Department of Transportation
Ray Lewis

Wisconsin Department of Transportation
Peter Amakobe

Worcester Polytechnic Institute
Malcolm Ray

A Guide for Addressing Head-On Collisions

BMI's staff participating in the project included

- Hugh McGee, Goal Area Manager;
- Forrest Council, Expert Advisor;
- Leanne Prothe, Project Engineer; and
- Kimberly Eccles, Project Engineer.

The participants from the demonstration states included

- Terecia Wilson, Director of Safety, South Carolina Department of Transportation;
- William Bloom, Director of Planning and Research, South Carolina Department of Transportation;
- Meg Moore, Engineer of Field Coordination, Traffic Operations Division, Texas Department of Transportation;
- Darren McDaniel, Transportation Engineer, Traffic Operations Division, Texas Department of Transportation; and
- Roy Peterson, Chief, Traffic Safety Programs, California Department of Transportation.

Numerous other states provided information on implementation of strategies within their states. These states include Iowa, Kansas, Maryland, Massachusetts, Michigan, Minnesota, Pennsylvania, North Carolina, Virginia, and Washington.

SECTION I
Summary

Introduction

This emphasis area addresses head-on crashes associated with highway (i.e., nonintersection) segments. A head-on crash typically occurs when a vehicle crosses a centerline or a median and crashes into an approaching vehicle. A head-on crash can also occur when a driver knowingly or unknowingly travels the wrong way in a traffic lane. Head-on crashes occur as a result of a driver's inadvertent actions—as with run-off-road (ROR) encroachments—or deliberate actions—e.g., executing a passing maneuver on a two-lane road.

Statement of the Problem

The 1999 statistics from the Fatal Analysis Reporting System (FARS) indicate that 18 percent of noninterchange, nonjunction fatal crashes were two vehicles colliding head-on. The percentage was the same for 1997 and 1998 data. In addition, these data reveal that

- 75 percent of head-on crashes occur on rural roads,
- 75 percent of head-on crashes occur on undivided two-lane roads, and
- 83 percent of two-lane undivided road crashes occur on rural roads.

The high percentage of head-on crashes on rural, undivided, two-lane roads might suggest that many head-on crashes relate to failed passing maneuvers. However, in nearly all cases, fatal head-on crashes occur in nonpassing situations. Of 7,430 vehicles involved in head-on crashes on two-lane, undivided roadway segments, only 4.2 percent involved a vehicle "passing or overtaking another vehicle" (1999 data). The corresponding percentage for rural roads was 4.3 percent. These low fatal-crash percentages are corroborated by two studies performed by the Federal Highway Administration's (FHWA's) Highway Safety Information System (HSIS). According to the studies, all crashes either were passing related or occurred in no-passing zones.

This does not imply that passing crashes should be excluded from a fatality-reducing program, just that strategies should likely be chosen to reflect that roughly 91 percent of the vehicles involved in fatal head-on crashes on two-lane, divided roadways are related to vehicles either "going straight" (68 percent of the total head-on fatalities) or "negotiating a curve" (23 percent of the total). Comparable percentages hold for the rural roads.

It might also be expected that a significant proportion of head-on collisions occur in construction zones—locations where the traffic pattern is altered and opposing lanes may be brought closer together than normal. However, FARS data indicate that in 1999 only 1.9 percent of noninterchange, nonjunction head-on crashes (90 of 4,713) occurred in construction zones. While this problem could intensify with an increasing presence of work zones in the future, it is clear that programs aimed at reducing fatalities in head-on collisions should concentrate on "normal" highway sections.

These statistics indicate that most head-on crashes are likely to result from a motorist making an "unintentional" maneuver—the driver falls asleep, is distracted, or travels too fast in a curve. There may be other contributing factors, such as alcohol use or speeding.

Given these factors, affecting head-on fatalities is clearly more complex (and perhaps more difficult) than just providing adequate passing zones. Indeed, most head-on crashes are similar to ROR crashes—in both cases, the vehicle strays from its travel lane. In cases involving unintentional maneuvers, the causes are likely to be very similar. Potential head-on crashes can become ROR crashes if there is no oncoming vehicle, and a ROR crash can become a head-on crash if the vehicle "overrecovers" into the opposing travel lane.

Programs and Strategies

Objectives

The objectives for reducing the number of head-on fatal crashes are to

- Keep vehicles from encroaching into the opposite lane,
- Minimize the likelihood of a car crashing into an oncoming vehicle, and
- Reduce the severity of crashes that occur.

These objectives are similar to those cited for ROR crashes (emphasis area 15.1; see Volume 6 of this report, the ROR guide). The objective of reducing the severity of crashes is covered under the ROR emphasis area.

For each objective identified (except for the third objective, which is discussed in Volume 6 of this report, the ROR guide), there exist various strategies (Exhibit I-1). Each strategy is described in detail in this guide. Strategies may fall into either of two categories—treatments implemented over extended sections of highway or treatments at selected spot locations.

EXHIBIT I-1
Objectives and Strategies for Addressing Head-On Crashes

Objectives	Strategies
18.1 A—Keep vehicles from encroaching into opposite lane	18.1 A1—Install centerline rumble strips for two-lane roads
	18.1 A2—Install profiled thermoplastic strips for centerlines
	18.1 A3—Provide wider cross sections on two-lane roads
	18.1 A4—Provide center two-way left-turn lanes for four- and two-lane roads
	18.1 A5—Reallocate total two-lane roadway width (lane and shoulder) to include a narrow "buffer median"
18.1 B—Minimize the likelihood of crashing into an oncoming vehicle	18.1 B1—Use alternating passing lanes or four-lane sections at key locations
	18.1 B2—Install median barriers for narrow-width medians on multilane roads

Other Head-On Strategies

Other head-on strategies that are also ROR ones include the following (they are discussed in Volume 6 of this report, the ROR guide):

- Enhanced delineation of sharp curves;
- Improved highway geometry, especially for horizontal curves, including design elements such as curvature, superelevation, and widening through the curve;
- Better pavement markings;
- Skid-resistant pavement surfaces;
- Improved shoulders to prevent ROR overrecovery, including paving, eliminating edge drops, and improving shoulder slopes; and
- Rumble strips to slow vehicles on approaches to hazardous locations.

Another approach to addressing safety problems in a comprehensive way is to replace the *independent* activities of engineers, law enforcement personnel, educators, judges, and other highway safety specialists with *cooperative* efforts, an approach reiterated in these guides.

SECTION II

Introduction

The American Association of State Highway and Transportation Officials (AASHTO) Strategic Highway Safety Plan identified 22 goals to pursue in order to reduce highway crash fatalities. Goal 15 is "keeping vehicles on the roadway," Goal 16 is "minimizing the consequences of leaving the road," and Goal 18 is "reducing head-on and across-median crashes." These three goals are addressed by three emphasis areas:

- Run-off-road (ROR) crashes,
- Head-on crashes, and
- Trees in hazardous locations.

The common solution to these goals and emphasis areas is to keep the vehicle in the proper lane. While this may not eliminate crashes with other vehicles, pedestrians, cyclists, and trains, it would eliminate many fatalities that result when a vehicle strays from its lane onto the roadside or into oncoming traffic.

This emphasis area addresses head-on crashes associated with highway (i.e., nonintersection) segments. A head-on crash typically occurs when a vehicle crosses a centerline or a median and crashes into an approaching vehicle. It can also occur when a driver knowingly or unknowingly travels the wrong way in a traffic lane. Head-on crashes occur as a result of a driver's inadvertent actions—as with ROR encroachments—or deliberate actions—e.g., executing a passing maneuver on a two-lane road.

One of the hallmarks of the AASHTO Strategic Highway Safety Plan is to approach safety problems in a comprehensive manner, both in the range of strategies and in the related emphasis areas. 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 and in a coordinated manner.

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

SECTION III

The Type of Problem Being Addressed

General Description of the Problem

The 1999 FARS statistics indicate that 18 percent of noninterchange, nonjunction fatal crashes were two vehicles colliding head-on. The percentage was the same for 1997 and 1998 data. In addition, these data reveal that

- 75 percent of head-on crashes occur on rural roads,
- 75 percent of head-on crashes occur on undivided two-lane roads, and
- 83 percent of two-lane undivided road crashes occur on rural roads.

The high percentage of head-on crashes on rural, undivided two-lane roads might suggest that many head-on crashes relate to failed passing maneuvers. However, in nearly all cases, fatal head-on crashes occur in nonpassing situations. Of 7,430 vehicles involved in head-on crashes on two-lane, undivided roadway segments, only 4.2 percent involved a vehicle "passing or overtaking another vehicle" (1999 data). The corresponding percentage for rural roads was 4.3 percent. These low fatal-crash percentages are corroborated by two studies performed by the Federal Highway Administration's (FHWA's) Highway Safety Information System (HSIS). According to the studies, all crashes either were passing related or occurred in no-passing zones. Both studies concluded that these types of passing crashes were not considered a significant problem (Alexander and Pisano, 1992; Mohamedshah, 1992).

This does not imply that passing crashes should be excluded from a fatality-reducing program, just that strategies should likely be chosen to reflect that roughly 91 percent of the vehicles involved in fatal head-on crashes on two-lane, divided roadways are related to vehicles either "going straight" (68 percent of the total head-on fatalities) or "negotiating a curve" (23 percent of the total). Comparable percentages hold for the rural roads.

It might be expected that a significant proportion of head-on collisions occur in construction zones—locations where the traffic pattern is altered and opposing lanes may be brought closer together than normal. However, FARS data indicate that in 1999 only 1.9 percent of noninterchange, nonjunction head-on crashes (90 of 4,713) occurred in construction zones. While this problem could intensify with an increasing presence of work zones in the future, it is clear that programs aimed at reducing fatalities in head-on collisions should concentrate on "normal" highway sections.

These statistics indicate that most head-on crashes are likely to result from a motorist making an "unintentional" maneuver—the driver falls asleep, is distracted, or travels too fast in a curve. There may be other contributing factors, such as alcohol use or speeding.

Given these factors, affecting head-on fatalities is clearly more complex (and perhaps more difficult) than just providing adequate passing zones. Indeed, most head-on crashes are similar to ROR crashes—in both cases, the vehicle strays from its travel lane. In cases involving unintentional maneuvers, the causes are likely to be very similar. Potential head-on crashes can become ROR crashes if there is no oncoming vehicle, and an ROR crash can become a head-on crash if the vehicle "overrecovers" into the opposing travel lane.

Specific Attributes of the Problem

Conventional wisdom suggests that it would be highway curves rather than tangents that would present drivers with particular negotiating problems. Vehicles would be expected to cross the centerline more frequently on curves. However, as shown in Exhibit III-1, the majority of head-on fatalities on all roads and on two-lane rural roads are on tangent sections. For all roads, 33 percent of the 1999 head-on fatal crashes were on curves and 67 percent on tangents. For two-lane rural roads, the percentage on curves increased to 37 percent. These results most likely reflect the fact that the largest proportion of road sections is tangent. However, it is clear that both tangents and curves have significant problems and warrant treatment. Therefore, specific strategies are suggested for both curved and tangent sections in this guide.

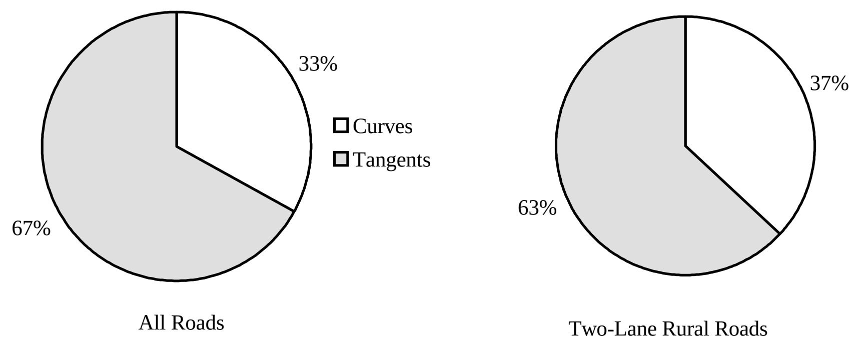

EXHIBIT III-1
Percentage of Head-On Fatal Crashes for Curves and Tangents for Two Categories of Road

SECTION IV

Index of Strategies by Implementation Timeframe and Relative Cost

Exhibit IV-1 classifies strategies according to expected timeframe and relative cost. In general, implementation time will depend upon such factors as the agency's processes and procedures for planning and programming and project development, the length of roadway involved, the need for additional right-of-way, and the need to complete environmental reviews and approvals. The range of costs may also vary somewhat for some of these strategies because of many of the same factors. A strategy's placement in the exhibit is meant to reflect its most common expected application under normal circumstances.

EXHIBIT IV-1
Classification of Strategies According to Expected Timeframe and Relative Cost

		Relative Cost to Implement and Operate			
Timeframe for Implementation	Strategy	Low	Moderate	Moderate to High	High
Short (<1 year)	18.1 A1—Install centerline rumble strips for two-lane roads	✓			
	18.1 A2—Install profiled thermoplastic stripes for centerlines	✓			
	18.1 A4—Provide center two-way left-turn lanes for four- and two-lane roads		✓		
Medium (1–2 years)	18.1 A5—Reallocate total two-lane roadway width (lane and shoulder) to include a narrow "buffer median"	✓			
	18.1 B1—Use alternating passing lanes or four-lane sections at key locations*			✓	
	18.1 B2—Install median barriers for narrow-width medians on multilane roads		✓		
Long (>2 years)	18.1 A3—Provide wider cross sections on two-lane roads*			✓	

* If additional right-of-way is required, this strategy could become a high-cost strategy.

SECTION V

Description of Strategies

Objectives

The objectives for reducing the number of head-on fatal crashes are to

- Keep vehicles from encroaching onto the opposite lane,
- Minimize the likelihood of crashing into an oncoming vehicle, and
- Reduce the severity of crashes that occur.

These objectives are similar to those cited for ROR crashes (emphasis area 15.1; see Volume 6 of this report, the ROR guide). Reduction in the severity of crashes is covered in that emphasis area. Specific strategies include improving the design of roadside hardware (e.g., bridge rails) and the design and application of barrier and attenuation systems.

Exhibit V-1 summarizes the objectives and strategies available to help system managers meet them.

EXHIBIT V-1
Objectives and Strategies for Addressing Head-On Crashes

Objectives	Strategies
18.1 A—Keep vehicles from encroaching into opposite lane	18.1 A1—Install centerline rumble strips for two-lane roads (T)[a]
	18.1 A2—Install profiled thermoplastic strips for centerlines (T)
	18.1 A3—Provide wider cross sections on two-lane roads (E)
	18.1 A4—Provide center two-way, left-turn lanes for four- and two-lane roads (T)
	18.1 A5—Reallocate total two-lane roadway width (lane and shoulder) to include a narrow "buffer median" (T)
18.1 B—Minimize the likelihood of crashing into an oncoming vehicle	18.1 B1—Use alternating passing lanes or four-lane sections at key locations (T)
	18.1 B2—Install median barriers for narrow-width medians on multilane roads (T)

[a] For an explanation of (T), (E), and (P), see the next page.

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, whereas others are used at state or even local levels. 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:

- 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 in frequent, or even general, use—should be applied with caution, carefully considering the attributes cited in the guide, and relating them to the specific conditions for which they are being considered. Implementation can proceed with some degree of assurance that there is not likely to be a negative impact on safety and very likely to be a positive one. It is intended that as the experiences of implementation of these strategies continues 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" (P) 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 proven not to be appropriate or feasible. 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 evaluations 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.
- Proven (P): Those strategies that have been used in one or more locations and for which properly designed evaluations have been conducted that show the strategies to be effective. These strategies may be employed with a good degree of confidence, but 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 the user judge which strategy is the most appropriate for the particular situation.

All but one of the strategies detailed in this guide are classified as "tried." That means that although they may be widely used, sufficient evidence of their effectiveness is not available to say that they have been proven to be effective.

Strategies may fall into two categories—those implemented over extended sections of highway or those implemented at selected spot locations. Just as the objectives for head-on crashes are similar to ROR crashes, so too are the strategies. Strategies common to both include

- Enhanced delineation of sharp curves;
- Improved highway geometry, especially for horizontal curves, including design elements such as curvature, superelevation, and widening through the curve;
- Better pavement markings;

- Skid-resistant pavement surfaces;
- Improved shoulders to prevent ROR over-recovery, including paving, eliminating edge drops, and improving shoulder slopes; and
- Rumble strips to slow vehicles on approaches to hazardous locations.

A discussion of these strategies is included in Volume 6 of this report, the ROR guide.

While some of the strategies presented in this guide may be appropriate for reducing head-on crashes on urban roadways, no strategies specifically for urban roads are included in this guide.

Related Strategies for Creating a Truly Comprehensive Approach

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

- Public Information and Education (PI&E) Programs—Many highway safety programs can be effectively enhanced with a properly designed PI&E campaign. The traditional emphasis with PI&E campaigns in highway safety is to reach an audience across an entire jurisdiction or a significant part of it. However, there may be reason 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.

  Where the application of PI&E campaigns is deemed appropriate, this guide is usually in support of some other strategy. In such a case, the description for that strategy will suggest this possibility (see the attribute area for each strategy entitled "Associated Needs"). In some cases, specialized PI&E campaigns are deemed unique for the emphasis area and are explained in detail within the guide. In the future, additional guides may exclusively address the details regarding PI&E strategy design and implementation. When that occurs, the appropriate links will be posted online at http://transportation1.org/safetyplan.

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

  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, 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 the impact of enforcement 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 unclear how the enforcement effort may impact behavior, or where it is desired to try an innovative and untried method, a pilot program is recommended.

As with PI&E campaigns, where the application of enforcement programs is deemed appropriate, this guide often supports some other strategy. In such cases, the description for that strategy will suggest this possibility (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 enforcement program will be explained in detail. In the future, additional guides may exclusively address the details regarding enforcement strategy design and implementation. When that occurs, the appropriate links will be posted online at http://transportation1.org/safetyplan.

- Strategies to Improve Emergency Medical and Trauma System Services—Treatment of injured parties at highway crashes can have a significant impact on the level of severity at which and length of time during 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 focused upon location-specific (e.g., corridors) or area-specific (e.g., rural area) 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. When that occurs, the appropriate links will be posted online at http://transportation1.org/safetyplan.

- Strategies Directed at Improving the Safety Management System—The management of the highway safety system is foundational to success in making the highway safety system safer. A sound organizational structure, as well as an infrastructure of laws, policies, etc., to monitor, control, direct, and administer a comprehensive approach to highway safety should be in place.

  It is important that a comprehensive program not be limited to one jurisdiction, such as a state DOT. Local agencies are often responsible for the majority of the roadway system and know its related specific safety problems. As additional guides are completed for the AASHTO plan, they may address the details regarding the design and implementation of strategies for improving safety management systems. When that occurs, the appropriate links will be posted online at http://transportation1.org/safetyplan.

- Strategies Detailed in Other Emphasis Area Guides—As mentioned in the previous section, many of the strategies in Volume 6 of this report (the ROR guide) are also effective in addressing head-on collisions. It is important that such strategies, effective for more than one emphasis area, are connected to all other related emphasis areas. As more guides are created, related links will be posted online at http://transportation1.org/safetyplan.

Comprehensive approaches are facilitated by involvement of as many of the potential stakeholders as possible. Appendix 12 provides a list of candidate types of stakeholders to consider including in the planning and implementation of a program.

Objective 18.1 A—Keep Vehicles from Encroaching into Opposite Lane

Strategy 18.1 A1—Centerline Rumble Strips for Two-Lane Roads (T)

General Description

Centerline rumble strips are similar to shoulder rumble strips. The purpose of rumble strips is to alert drivers who may inadvertently stray or encroach into opposing lanes. While this is a relatively new treatment, it has been implemented by some states, including Minnesota, Pennsylvania, Colorado, Delaware, Maryland, California, Washington, and Virginia. Other states, like Kansas, are still evaluating the use of centerline rumble strips in experimental installations.

EXHIBIT V-2
Centerline Rumble Strips Implemented in Maryland

Although there is no standard design, the rumble strip is generally wider than the center markings, extending into the travel lane by 5 in. to as much as 1.5 ft. In some states, the strips are continuous along the centerline; in others, they alternate with a smooth gap.

Since centerline rumble strips do not require changes in the overall cross section of the roadway, they would be compatible with other strategies such as shoulder rumble strips and horizontal curve improvements. This strategy, although fairly widely used, has not been sufficiently evaluated to be considered “proven.”

EXHIBIT V-3
Strategy Attributes for Centerline Rumble Strips on Two-Lane Roads (T)

Technical Attributes	
Target	Drivers of vehicles who unintentionally cross the centerline.
Expected Effectiveness	Although some literature sources report on the effectiveness of shoulder rumble strips, use of centerline rumble strips is relatively new and so there are very few reports concerning its success or failure. However, the findings below indicate that centerline

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EXHIBIT V-3 (Continued)
Strategy Attributes for Centerline Rumble Strips on Two-Lane Roads (T)

rumble strips are a promising countermeasure to reduce ROR collisions, and further study of their effectiveness is warranted.

In Pennsylvania, the major testing program involving implementation of centerline rumble strips began in 2001, and thus formal evaluation is not yet possible. Pennsylvania installed centerline rumble strips on a 6-mile section of Route 322 in 1993. In the 6 years following the installation, there were no fatal accidents. However, centerline rumble strips were only one part of a treatment package that included separating lanes by a narrow "buffer median" and other modifications. Centerline rumble strips were also installed on some roadways in Delaware. The 1995 *Annual Report on Highway Safety Improvement Programs for the State of Delaware* reported a reduction of head-on collisions where centerline rumble strips were installed. The results are tabulated below:

Head-On Crashes on a Two-Lane Rural Highway in Delaware Before and After Use of Centerline Rumble Strips

	Head-On Crash Frequency	
Severity of Crash	**36 Months Before**	**24 Months After**
Fatal	6	0
Injury	14	12
Damage only	19	6
Total	39	18
Crashes per month	1.1	0.76

NCHRP Report 440 (Fitzpatrick et al., 2000) describes the installation of centerline rumble strips as part of “the improvements that could correct driver behavior in a manner that would reduce fatal head-on accidents.” The improvements were made to a 20-mile rural two-lane segment in California. For nonpassing sections of the roadway, centerline double yellow strips were replaced with a 16-in. (40.6-cm)-wide rumble strip and raised profile traffic striping. Additional centerline improvements included raised markings for passing sections, and shoulder treatments included rumble strips and raised markings. A limited accident review using 34 months of before data and 25 months of after data did show a reduction in accidents. On average, 4.5 accidents occurred per month in the before period and 1.9 accidents per month occurred in the after period.

These studies appear to involve “high-crash sites.” Due to the “regression to the mean” bias, the estimates of effectiveness are probably inflated to some degree. Thus, there remains a need for well-designed before/after studies that can produce more accurate results of effectiveness.

Centerline rumble strips have not been sufficiently evaluated to be considered a proven strategy. However, this strategy was tried and accepted in a number of applications. Additionally, there have been no significant findings of negative effects from the use of centerline rumble strips.

EXHIBIT V-3 (Continued)
Strategy Attributes for Centerline Rumble Strips on Two-Lane Roads (T)

Keys to Success	To be effective, centerline rumble strips must be implemented over a continuous length of facility. It may not be cost-effective to implement this strategy on all undivided road sections. Therefore, a key to success is identifying the characteristics of the roadway (traffic volume, speed, alignment quality, cross section) for which rumble strips may be expected to have the greatest positive effect.
Potential Difficulties	Shoulder rumble strips have either real or perceived drawbacks such as difficulty with snow removal, additional shoulder maintenance requirements, and undesirable noise levels. States not using rumble strips may have concerns about these effects. However, states that use rumble strips (on the roadway shoulder or otherwise) have not reported any additional maintenance requirements as long as the rumble strips are placed on pavement that is in good condition. This pitfall may make centerline rumble strips an expensive countermeasure if targeted implementation is not achieved (i.e., if an agency tried to implement rumble strips everywhere) and measurable benefits are not accomplished. In a related vein, an effective implementation strategy may be to deploy centerline rumble strips in conjunction with resurfacing or reconstruction projects. This may, however, forestall the overall systemwide benefits sought by AASHTO over the short term. There is the possibility of adverse effects on motorcycling. Note, however, that Pennsylvania has worked with motorcycle groups, and no major concerns were raised by these groups. Finally, it is possible that the use of a centerline rumble strip might have some negative operational effects by inhibiting passing maneuvers (due to the look and noise of the strip). However, states currently using these rumble strips have not reported such problems (e.g., Washington, Minnesota, Pennsylvania).
Appropriate Measures and Data	In an evaluation of centerline rumble strip programs, *process measures* would include the number of road miles or number of hazardous locations where rumble strips are installed. Process measures may also include the aspect of exposure—number of vehicle miles of travel exposed to centerline rumble strips. *Impact measures* will include the number (or rate) of head-on crashes reduced at these locations, along with any change in total crashes. Another measure may be public acceptance, including complaints from roadway users and even nonusers adjacent to the road. Accident data, traffic volume data, and roadway data will be required to identify appropriate sites for installation.
Associated Needs	Since this countermeasure is relatively new (unlike shoulder rumble strips), there may be a need for public information to explain the function of the treatment in order to address any public concerns or potential misunderstandings. Such campaigns may address the concerns of motorcyclists and the education of the motoring public regarding the effects of centerline rumble strips on passing maneuvers.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	These strategies will be implemented by state and local roadway agencies, and it does not appear that extra coordination with other agencies or groups is needed. Since proof of effectiveness will be what sells this treatment in the long term, this effort will be most effective when reporting and analyzing head-on crashes becomes routine. It will also be most effective when a framework and a methodology exist targeting the implementation to the most appropriate sites. The framework and methodology will include institutionalizing centerline rumble strips within an agency's design standards and policies, as appropriate.

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EXHIBIT V-3 (Continued)
Strategy Attributes for Centerline Rumble Strips on Two-Lane Roads (T)

Issues Affecting Implementation Time	This low-cost strategy does not involve reconstruction and would not involve the environmental process or right-of-way acquisition. Rumble strips can be implemented quickly, certainly within a year once a site or highway is selected. Programmatic implementation may take slightly longer, depending on availability of necessary traffic, crash, and roadway data within an agency. Incorporation of centerline rumble strips as part of an agency's design practice for new construction or resurfacing can occur quickly (within 1 year).
Costs Involved	Costs will vary depending on whether the strategy is implemented as a stand-alone project or incorporated as part of a reconstruction or resurfacing effort already programmed. Including rumble strips as part of a resurfacing project offers the opportunity for lowest cost implementation. Some recent cost figures are given in Appendix 11.
Training and Other Personnel Needs	There appear to be no special personnel needs for implementing this strategy. States would either use agency personnel or contractors. Training of state safety engineers on the attributes, benefits, and applicability of centerline rumble strips would be necessary. Training regarding actual installation of the rumble strips would depend on whether the agency has been using retrofitted rumble strips on freeways or other roadways. If not, either agency personnel or contractor personnel would need to be trained in proper installation techniques.
Legislative Needs	None identified.
Other Key Attributes	
None Identified	

Information on Agencies or Organizations Currently Implementing this Strategy

Washington, Maryland, Minnesota, Virginia, and Pennsylvania DOTs have provided information on current use. Kansas has provided information on plans for installation. Washington reports it is using raised discs, raised pavement markers, or plastic strips to get the rumble effect. These are being used continuously along a route in both passing and no-passing zones, and passing maneuvers do not seem to be affected. Washington also reported that drivers are using the raised discs and markers as a guide when the centerline is not visible due to winter weather. Maryland has used them primarily on access-controlled highways. For example, the "treatment package" on Maryland Route 90 includes a wider center yellow line combined with raised pavement markers and rumble strips. Information on Maryland's program can be found in Appendix 1. Minnesota has implemented strips on a limited basis without any current problems. Virginia installed centerline rumble strips on approximately 2 miles of two-lane roadway and found no initial problems with the installation. Information on Virginia's program can be found in Appendix 2. Pennsylvania reports both public acceptance and no centerline obscuring in a pilot effort there. In Kansas, installation of centerline rumble strips was to begin in summer 2001. Information on Kansas's program can be found in Appendix 3.

Strategy 18.1 A2—Profiled Thermoplastic Stripes for Centerline

General Description

This treatment has been used for centerlines on two-lane roads by at least two states—California and Texas. Standard plans used in Texas are included as Appendix 4. Both states use this treatment for sections where passing is not permitted. North Carolina has used this treatment to mark both sides of a two-way, left-turn lane on a multilane roadway. The 6-in. yellow profile thermoplastic stripes are installed on a 15-mile section of U.S. 158.

This treatment provides an audible/tactile effect, but it is less noticeable for larger vehicles, especially trucks. This effect is similar to that experienced with raised pavement markers with short spacing. While the audible/tactile effect can be advantageous, its principal benefit is apparently the longer visibility distance provided at night, especially during wet conditions, when compared with standard pavement markings. However, as with standard raised pavement markers, this treatment would be limited to areas where there is little or no snow, as snow plow blades will easily scrape off the stripe.

This strategy, although used in several states, has not been sufficiently evaluated to be considered "proven."

EXHIBIT V-4
Strategy Attributes for Profiled Thermoplastic Stripes for Centerlines (T)

Technical Attributes	
Target	Motorists who unintentionally cross the centerline of a roadway.
Expected Effectiveness	Although both California and Texas have used this treatment on significant mileage of roadways, there has not been any formal evaluation. The anecdotal information is that this treatment provides good visibility of the centerline during night conditions and that even the mild audible and tactile effect is useful for reminding motorists to keep right of the centerline. There is no known evaluation of changes in accidents or in changes in any driver performance measure with the use of this treatment for a centerline. Caltrans has been using this treatment on an experimental basis since 1993, but no longer considers it experimental. This treatment has not been sufficiently evaluated to be considered a proven strategy. However, there have been no significant findings of negative effects of this strategy.
Keys to Success	While no agency has identified specific guidelines on where this treatment could be applied, it would seem that it may be a reasonable option for two-lane rural roads under the following conditions: • Snow removal is not required. • Sections of no-passing zones are relatively long. • Volume levels and head-on related crash experience do not justify centerline rumble strips or some other more costly treatment. • Resurfacing or other pavement maintenance activities that would cause removing the treatment are not scheduled for at least 3 years. • Areas are of higher-than-normal rainfall. Additionally, Caltrans has used this strategy as an incremental improvement while a more cost-intensive project is being designed and funded.

(*continued on next page*)

EXHIBIT V-4 (Continued)
Strategy Attributes for Profiled Thermoplastic Stripes for Centerlines (T)

Potential Difficulties	There are no significant obstacles or difficulties in using this treatment. There have not been any adverse effects reported for motorcyclists. Application of the patterns illustrated above is easily accomplished with standard thermoplastic machines. One other cautionary note about its use is that it may not be suitable for open-graded or seal-coated surfaces.
Appropriate Measures and Data	In an evaluation of this treatment, process measures would be the same as for rumble strips—the number of road miles or number of locations where this treatment is installed. The exposure measure would be the vehicle miles of travel exposed to the treatment. Performance measures are also the same as for rumble strips and include the number (or rate) of head-on crashes reduced at the locations. Public acceptance and preferences from road users would also be an appropriate measure.
Associated Needs	There should not be any special needs, such as a public information program, since this treatment is not likely to surprise motorists. Raised pavement markers are fairly common and this treatment is similar to that application.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	Since this strategy is similar to normal pavement-marking practices, vis-à-vis standard flat thermoplastic stripes and raised pavement markers, there should not be any special issues. Those jurisdictions that use this treatment will want to conduct their own evaluations to establish whether the treatment is a cost-effective strategy.
Issues Affecting Implementation Time	Implementation of this treatment can be almost immediate, which makes it an appealing initial strategy to address an identified head-on crash problem on two-lane roads.
Costs Involved	When considering cost on a life-cycle basis, the thermoplastic stripe becomes less costly than standard paint striping. Its use also will result in a reduction of potential conflicts with maintenance vehicles operating under traffic because of the reduced frequency of application needed. Some example costs for 2002 are given in Appendix 10.
Training and Other Personnel Needs	There are no special personnel or training needs for implementing this strategy. States vary as to whether or not they use their own forces for applying thermoplastic markings.
Legislative Needs	None identified.
Other Key Attributes	
None Identified	

Information on Agencies or Organizations Currently Implementing this Strategy

Caltrans seems to be the state most active with this application. Caltrans has applied this treatment—as both centerlines and edgelines—on a significant mileage of two-lane rural roads that were identified as safety problem corridors. While no specific evaluation has been conducted, Caltrans managers think that the treatment has helped improve the safety of the corridor. For several years, the treatment was considered experimental; it is now considered a standard treatment under the guidelines discussed above. See Appendix 8 for further details.

Strategy 18.1 A3—Two-Lane Highways with Wide Cross Sections

General Description

Even though there is a broad range of definitions for the "Super Two" design in both the United States and Europe, most definitions are characterized by wider cross sections. These designs include wider lanes, wider full-strength shoulders, and high-speed alignment with 100-percent passing sight distance. A common design for the United States includes 14-ft travel lanes, 10-ft shoulders, and a design speed of 70 mph. The design may also include alternating passing lanes and sometimes two-way left-turn lanes.

These designs have been proposed by some DOTs as a substitute for more costly conversion to or construction of four-lane divided roadways, while offering primarily capacity and level of service improvements. Although the "Super Two" design is not promoted as a safety improvement, it has been acknowledged that safety benefits might be expected for these designs when compared with conventional two-lane rural highways. Moreover, agencies employing this strategy may spend less than the alternative (reconstructing a corridor to a four-lane divided facility).

The combination of alignment and cross section is intended to minimize the potential adverse effects of cross-centerline conflicts and to reduce excursions onto the roadside. However, it is noted that such designs employ high design speeds (75 mph, or 120 km/h). As such, their application would be incompatible with other strategies intended to lower speeds and reduce crash severity.

Implementation of these wider cross sections involves reconstruction of a road or construction on new alignment. As such, this strategy is clearly among the higher cost of those considered. Moreover, implementing the design change typically entails the environmental process and often includes right-of-way acquisition, both of which by their nature typically require a substantial timeframe. From project inception through planning, design, and construction, a 5- to 10-year timeframe is typical for such projects.

Given the direction by AASHTO to focus on low-cost, short-term-oriented strategies, the use of these designs would appear to be outside the scope of the AASHTO Strategic Highway Safety Plan. However, it is included here since it is a new approach to highway design, having apparent safety benefits, being considered by states. States may wish to consider this strategy within the context of an overall review of their design process for their two-lane system.

The design is currently being used in an experimental or pilot mode. There has not been sufficient experience with this design, nor has the design been adequately evaluated, for the design to be used in any significant way. Pilot testing should be employed before this design is used widely. As results of current evaluations become available, the efficacy of this strategy will become better known.

EXHIBIT V-5
Strategy Attributes for "Wider Cross-Section" Designs (E)

Technical Attributes	
Target	Drivers on two-lane roads susceptible to head-on crashes. (It could apply to other types of crashes as well.)
Expected Effectiveness	There are very limited North American data available on the safety effectiveness of these wider cross-section designs. The Iowa DOT, a proponent of the "Super Two" design, estimates that overall safety performance will be between that of a four-lane divided road and that of a typical two-lane highway. Some European studies, however, have not indicated the same positive effects. These two examples provided will need further experimentation and review. Therefore, this strategy is a likely candidate for pilot implementation only at this time.
Keys to Success	The keys to success will be sound evaluations that can define the safety-related effectiveness. This suggests the need for prototype studies conducted under carefully monitored conditions using a properly designed evaluation study. Other keys to success include establishing a set of acceptable and proven design standards to promote use of the safest design, developing state "champions" to sell the idea to other states if effective, and incorporating the design into the standard design process. Other keys will include gaining acceptance by the public and local stakeholders, many of which have expressed concerns over the "Super Two" concept, preferring instead four-lane divided highway improvements.
Potential Difficulties	The major pitfalls are cost and time to implement. This strategy involves complete reconstruction, unlike some other strategies. Note also that this strategy would be impractical in geographies with difficult terrain (mountainous and heavily rolling) due to the cost of providing 100-percent passing sight distance and high design speeds. Finally, if the higher-speed design is implemented without increases in roadside clear zone, there may be an increase in serious run-off-road crashes.
Appropriate Measures and Data	In the evaluation of these wider cross-section designs, process measures would include the number of road miles or number of hazardous locations where these cross sections are implemented. Impact measures would include the number of head-on crashes reduced at these locations, along with any other changes in total crashes (either positive or negative). If Super Twos or other wider cross-section designs are shown to improve safety in relation to other alternatives (e.g., four-lane divided or four-lane undivided designs), there will also be a need for developing better "targeting" tools—guidelines for when the design is the best alternative.
Associated Needs	Since this is a new design that will "compete with" traditional multilane designs, which the public feels are good, there will be a need for a program to inform the public why this design is being implemented. Where the designs have been proposed, public reaction has been mixed or negative. The public and business communities tend to lobby for or support projects that reconstruct or replace a two-lane road with a multilane highway. The latter are viewed positively in terms of the high and consistent level of service. Super Twos and other wider cross-section designs are not viewed favorably in this respect. Agencies must be careful not to send mixed messages to the public regarding Super Two and other wider cross-section designs. DOTs often sell the safety benefits of multilane highways in rural areas; thus, their substitution of Super Two designs for the traditional multilane design may not be understood or may be viewed as accepting a lesser level of safety. Indeed, there is no evidence that such designs are as safe as multilane divided designs, and they are not likely to be as safe given the lack of a median dividing opposing flows.

EXHIBIT V-5 (Continued)
Strategy Attributes for “Wider Cross-Section” Designs (E)

Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	Since this is a new design for major realignments, its implementation depends on an innovative state design agency. Since implementation more than likely includes the environmental process, a cooperative planning process involving federal and state regulatory agencies as well as the state DOT will be needed.
Issues Affecting Implementation Time	Implementation would greatly depend on the project limits, the specific circumstances described above, and funding available. This would probably involve between 5 and 10 years.
Costs Involved	Because this strategy involves complete reconstruction, costs can vary greatly depending on the specific needs at each site and the length of the wider cross section. In general, the costs of constructing a two-lane rural highway with high-quality geometry are on the order of $1–3 million per mile, exclusive of right-of-way costs.
Training and Other Personnel Needs	There appear to be no special personnel or training needs for implementing this strategy.
Legislative Needs	None identified.
Other Key Attributes	
Until proven otherwise, this design should be considered inferior to certain other construction strategies (construction of four-lane divided highways) that would be expected to produce lower fatal crash experience. Thus, there would appear to be a clear tradeoff between levels of safety and construction and right-of-way costs.	

Information on Agencies or Organizations Currently Implementing this Strategy

Iowa, Minnesota, Washington, and Kansas have used wider cross-section designs in certain locations. Usage is relatively new in each state. While Iowa, Minnesota, and Kansas have not noted any major problems, Washington noted significant problems with subsequent head-on crashes and converted the design to one involving alternating passing lanes. Information on Washington’s, Iowa’s, and Minnesota’s programs can be found in Appendix 5, Appendix 6, and Appendix 7, respectively. Finally, Texas has recently asked the Texas Transportation Institute at Texas A&M to study this design for possible future use in Texas.

Strategy 18.1 A4—Center Two-Way, Left-Turn Lanes on Four-Lane and Two-Lane Roads

General Description

This strategy involves the development of two-way, left-turn lanes (TWLTLs) on existing roadways. It can be accomplished either by the conversion of four-lane undivided arterials to three-lane roadways with a center left-turn lane or by the more conventional reconstruction of a two-lane road to include the TWLTL. Since the latter could be a costly conversion because it may require new right-of-way, the four-lane road conversion is considered more appropriate to the AASHTO emphasis on low-cost alternatives. However, where right-of-way cost is not a major consideration, the inclusion of TWLTLs on existing two-lane roads may be an even more effective treatment for head-on collisions since more of such collisions would likely occur on two-lane roads than on four-lane roads.

The development of TWLTLs is usually for traffic operations rather than safety concerns. TWLTLs are usually implemented to improve access. When they are used in response to a safety concern, the use is traditionally to reduce driveway-related turning and rear-end collisions. However, because studies have also indicated a positive effect on head-on crashes, the strategy is included here. The principle behind the use of TWLTLs in this context is to provide a buffer between opposing directions of travel. The strategy is intended to reduce head-on crashes by keeping vehicles from encroaching into opposing traffic lanes through the use of the buffer.

It is also noted that the conversion of *urban* four-lane undivided streets to two through lanes with a TWLTL is now often referred to as a "road diet" or "street diet." There is a growing body of information on these urban conversions, which are usually done to better accommodate pedestrians, bicyclists and other road users through the resulting decreases in travel speeds and less hazardous street crossings (see Knapp and Giese, 2001, for example). However, since head-on collisions are a more significant problem in rural areas, this section focuses on rural conversions/additions to TWLTLs.

While there will be very few passing-related, head-on crashes on undivided four-lane roads, head-on collisions can result from a vehicle inadvertently leaving its lane and crossing the centerline or from a vehicle attempting to turn left across oncoming traffic. (While this crash could be termed a "turning" crash, it is sometimes termed "head-on," and the severity can be the same as a head-on crash.) The strategy can reduce head-on collisions in two ways. First, turning-related, head-on crashes are made from the left-turn lane rather than a through lane, giving the driver a more protected (and thus less pressured) location to make judgments concerning acceptable gaps in the oncoming flow. Second, the center left-turn lane provides a "clear zone" or median between opposing vehicles, allowing drivers to leave their lanes but to recover and return safely.

This strategy, although fairly widely used, has not been sufficiently evaluated to be considered "proven." It *should* be compatible with other strategies for head-on and ROR crashes (e.g., shoulder rumble strips, improved pavement markings, and horizontal curve improvements). With respect to the driving public, it should be particularly helpful to local drivers who must turn left across traffic into private or business driveways. It may also be compatible with improving the safety of unsignalized intersections and improving the safety of pedestrians by reducing the number of traffic lanes to be crossed.

EXHIBIT V-6
Strategy Attributes for Conversion of Four-Lane Undivided Arterials to Three-Lane TWLTL Designs

Technical Attributes	
Target	Drivers crossing the centerline of an undivided multilane roadway inadvertently and drivers attempting to make a left turn across oncoming traffic. Roads to be targeted would be those where traffic volumes make it feasible to reduce the number of lanes to two through lanes (generally 15,000 vehicles per day [vpd] or less), or where alternative parallel routes exist for diversion of traffic.

EXHIBIT V-6 (Continued)
Strategy Attributes for Conversion of Four-Lane Undivided Arterials to Three-Lane TWLTL Designs

Expected Effectiveness

A number of publications provide indications of the effectiveness of this strategy. *NCHRP Report 282* (Harwood, 1986) and *NCHRP Report 420* (Gluck et al., 1999) looked at access management strategies including three-lane designs. But as with other countermeasures, the road sections used in the analysis were not restricted to rural two-lane roads. In fact, *NCHRP Report 282* uses traffic volume, speed, spacing of intersections, number of access points, on-street parking, and area population to identify road sections labeled as suburban arterial highways. More analysis specific to quantifying the effectiveness of cross-sectional design alternatives on rural two-lane roads is needed. Nevertheless, some of the statistics and conclusions in those reports are summarized below to show the effectiveness of such roadway conversions on other roadway types.

NCHRP Report 282 uses data from California and Michigan to establish a database for suburban highways. Using this database, accident rate estimates (accidents per million vehicle miles) were obtained for various multilane design alternatives. The table below displays the average accident rate for nonintersection accidents. The report also gives further adjustment factors to these rates based on truck percentage, number of driveways per mile, and shoulder width. These adjustment factors are not displayed below.

Basic Accident Rates for Five Design Alternatives (Accidents per Million Vehicle Miles)

	Type of Development	
Design Alternative	**Commercial**	**Residential**
Two-lane, undivided	2.39	1.88
Three-lane, TWLTL	1.56	1.64
Four-lane, undivided	2.85	0.97
Four-lane, divided	2.90	1.39
Five-lane, TWLTL	2.69	1.39

From this table, the commercial three-lane TWLTL (3T) design accident rate is 45 percent less than the four-lane undivided (4U) design accident rate. Thus, 45 percent is a reasonable estimate for the accident reduction effectiveness of altering a 4U design to a 3T design. However, engineering judgment and specific location attributes should also be considered when estimating the accident reduction benefit.

Two other study results indicate that there seems to be a roadway volume threshold where the increase in delay is minimal compared with the resulting accident reduction. A 1978 study found that installing a 3T design on a highway with an existing 4U design and an average daily traffic (ADT) of 16,000 vpd resulted in an increase in delay because of the reduction of through lanes. However, a 1981 study conducted on a facility with a lower traffic volume found no increase in delay and a substantial reduction in accidents.

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EXHIBIT V-6 (Continued)
Strategy Attributes for Conversion of Four-Lane Undivided Arterials to Three-Lane TWLTL Designs

	NCHRP Report 420 states that highway facilities with TWLTLs had accident rates that were, overall, roughly 38 percent less than those experienced on undivided facilities (Gluck et al., 1999). This percentage is calculated using statistics from 12 studies conducted since 1970. The three studies that evaluated the conversion of four-lane undivided facilities to three-lane facilities with TWLTLs specifically calculated the following reductions: 9 percent decrease in accident rate, 28 percent decrease in accident rate, and 40 percent decrease in number of accidents.
	A study by Fitzpatrick and Balke (1995) compared the accident rates of rural, four-lane roadways with TWLTLs and similar roadways with flush medians. They found no significant difference in the accident rates of the two median treatments in rural areas, when the roadways had comparable speed limits and driveway densities. Although this study looked at four-lane roadways and not two-lane roadways with TWLTLs or flush medians, there would seem to be a similarity between the two. Therefore, the crash experience of this design would likely be comparable to a roadway with a flush "buffer median." Refer to Strategy 18.1 A5 for more information on buffer medians.
	In recent work related to the Interactive Highway Safety Design Module for two-lane rural roads, an expert panel developed a series of accident modification factors (AMFs) based on a critical review of available literature. The AMF for adding a TWLTL was based on the review by Hauer (1999) and was found to be a function of access point density (i.e., APD, the number of driveways and unsignalized intersections per mile) and the number of access-point-related crashes. The addition of the turn lanes was found to be beneficial only where there were more than 5 access points per mile (3 points per kilometer). For higher densities, the AMF (which can be multiplied by the existing mean number of total crashes on the section) is as follows:
	$\text{AMF} = 1 - 0.07\, P_{AP}\, P_{LT/AP}$,
	Where
	P_{AP} = access-point-related crashes as a proportion of total crashes
	$= (0.0047\text{APD} - 0.0024\text{APD}^2) / (1.199 + 0.0047\text{APD} + 0.0024\text{APD}^2)$
	$P_{LT/AP}$ = left-turn crashes susceptible to correction by the TWLTL as a proportion of access-point-related crashes. This is estimated as 0.5.
	In summary, there are a number of studies summarizing the effects of a conversion from the current cross-section geometry to inclusion of a TWLTL. However, this strategy cannot be considered a proven strategy because there are no truly valid estimates of the effectiveness of such conversions based on sound before/after studies for a two-lane road. There have been no significant findings of negative effects of this strategy. Precise estimates of effectiveness should be developed in well-designed evaluations of pilot conversions.
Keys to Success	Successful application of this strategy will be based on the ability to identify road segments with sufficiently high speeds and traffic volumes such that serious head-on crash frequencies are significant, yet traffic volumes are low enough that operation with one through lane in each direction is feasible. If inappropriate sites are selected for this countermeasure, illegal passing in the TWLTL may occur as a result of eliminating the passing possibility. It may also require communicating the benefits of such improvements to the public and business owners, who may view such improvements as reducing the capacity of the roadway.
Potential Difficulties	Using this strategy in locations with traffic volumes that are too high could result in diversion of traffic to routes less safe than the original four-lane design. It may also result in congestion levels that contribute to other crashes. While a crash reduction might occur on the modified roadway, this diversion could result in an overall increase in crashes in the system.

EXHIBIT V-6 (Continued)
Strategy Attributes for Conversion of Four-Lane Undivided Arterials to Three-Lane TWLTL Designs

	Other pitfalls concern public and business owners' acceptance of a plan that appears to reduce the highway's traffic-carrying capacity. Also, the relative safety of unsignalized intersections along the route may be influenced adversely. By consolidating through traffic into one lane in each direction, the potential exists to decrease the number of gaps and increase the amount of risk taking by drivers queued at stop signs on minor approaches. Although the *number* of gaps may be reduced, thereby increasing the risk, the gaps will become less complex since drivers are now dealing with one lane in each direction and the TWLTL can be used as a refuge and for acceleration. Thus, the potential pitfall of a decrease in the number of gaps may be countered by the decrease in the complexity of the gap.
Appropriate Measures and Data	In implementation evaluations, *process measures* would include the *number of road miles or number of hazardous locations* where such conversions are implemented. *Impact measures* will include the *number of head-on crashes reduced* at these locations, along with any change in total crashes.
Associated Needs	A public information effort would be needed to educate both the normal commuting drivers and the roadside businesses concerning the effects of this strategy.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	This strategy would be implemented by the state DOT or local highway agency, and it does not appear that extra coordination with other agencies would be needed. However, since this would affect access to neighborhood businesses and residences (and should be advantageous to both), a planning/public hearing process that involves these groups should help facilitate treatment implementation. No immediate policy changes are required. Should this strategy prove effective, DOT and other agencies may find it advantageous to adjust their design policies to incorporate three-lane designs as alternatives to four-lane undivided roadways for certain traffic conditions.
Issues Affecting Implementation Time	Implementation would require more time than in some low-cost treatments. However, assuming no new right-of-way would be required, environmental analyses and documentation would be minimal and readily accomplished, and the modification would require only new lane markings. This strategy could be implemented within a short time period.
Costs Involved	Costs should be relatively low since this strategy involves only re-marking of existing pavement and minor improvements to markings and signalization at intersections.
Training and Other Personnel Needs	There appear to be no special personnel or training needs for implementing this strategy.
Legislative Needs	None identified.
Other Key Attributes	
None Identified	

Information on Agencies or Organizations Currently Implementing this Strategy

Iowa DOT is implementing this strategy on several urban arterial streets and on short sections of main highways through local communities. While the research team is not aware of other states developing such center-turn lanes through modification or addition in rural areas, this basic TWLTL design has been used for a number of years.

Strategy 18.1 A5—Reallocation of Total Two-Lane Width (Lane and Shoulder) to Include a Narrow "Buffer Median"

General Description

Head-on fatalities are affected both by the number of vehicles that cross the centerline and by the speed of oncoming vehicles. A particularly effective strategy might be affecting both factors by reallocating the existing cross section—narrowing lanes to encourage slower speeds while incorporating a narrow buffer median between opposing flows. For example, a high-speed rural two-lane roadway with a cross section consisting of 12-ft lanes and 10-ft paved shoulders could be restriped to provide narrower shoulders (e.g., 8 ft) or slightly narrower lanes (e.g., 11 ft), with the difference forming a 6-ft flush median divider. The median could include milled-in centerline rumble strips to help prevent inadvertent crossings.

Any number of combinations of lane and shoulder width could be considered, producing a median separation of 1 ft to 6 ft, and additional paved shoulders could be added if needed. Recent research suggests that total roadway width (lanes and shoulders) influences the safety of two-lane roads. Review of existing empirical evidence by Hauer indicates that the safety performance of roadways with 11-ft lanes is about as good as or slightly better than that of roadways with 12-ft lanes (Hauer, 2001). Indeed, in Europe, the concept of "optical narrowing" of lanes is employed to slow travel speeds.

The strategy would be most effective where reallocation of roadway width could be accomplished without degrading the roadside clear zone. As noted in the section concerning current implementation following the table below, this strategy has only been implemented in limited cases and should be considered experimental at this point. However, as will be noted there, both Pennsylvania and Maryland have implemented similar strategies with promising results. Information on Maryland's program can be found in Appendix 1.

This strategy, although tried in several locations, has not been sufficiently evaluated to be considered "proven." This design should be compatible with shoulder rumble strips, curve improvements, and other two-lane treatments (except shoulder widening). However, this strategy would be incompatible with ROR strategies if its implementation required narrowing the shoulder or otherwise reducing the quality of the roadside.

EXHIBIT V-7
Strategy Attributes for Reallocation of Total Width to Provide Median Buffer

Technical Attributes	
Target	Drivers of vehicles who unintentionally cross the centerline.
Expected Effectiveness	In development of this guide, evaluation studies documenting the effectiveness of the narrow buffer medians without barriers on two-lane roads were not found. The strategy appears promising, however, given Pennsylvania's experience with a similar treatment of converting a two-lane roadway section with a passing lane to a two-lane roadway with a buffer median, including centerline rumble strips. Maryland did implement a buffer-median treatment, including a median guardrail on sections of two access-controlled, two-lane state routes. The before/after analyses indicated a reduction in total and opposite direction (head-on) crash rates of

EXHIBIT V-7 (Continued)
Strategy Attributes for Reallocation of Total Width to Provide Median Buffer

	approximately 50 percent. However, it must be noted that these sections were "high-accident" sections prior to the treatment, meaning that the studies could be subject to "regression to the mean" bias. In addition, the number of head-on crashes studied was usually quite small, ranging from one to five per year. Finally, positive improvements in severity were not measured. Clearly, these results are promising; however, additional evaluation is needed before this strategy can be considered a proven strategy. Measurable effectiveness would seem to be achievable. Additionally, there have been no significant findings of negative effects of median buffers.
Keys to Success	The initial key to success would be experimental use and careful evaluation to determine effectiveness, cost, and adverse consequences. If effective, there will need to be effort toward identifying the characteristics of the roadway (traffic volume, speed, alignment quality, cross section) for which this buffer median may be expected to have the greatest positive effect.
Potential Difficulties	Given that this is a new and somewhat unproven design, the major difficulties will be objections raised by highway agencies such as the potential of lessening the public's willingness to pass, difficulty with snow removal, loss of shoulders for disabled vehicles, and undesirable noise levels (associated with the rumble strips). A sample of state DOT representatives who reviewed this concept suggested that the buffer median would be much less effective if only delineated by paint. They suggested the use of rumble strips in the median at a minimum. However, this was expressed opinion, rather than based upon any solid evaluation. No studies regarding the effectiveness of buffers with either treatment have surfaced. There is also a concern that traffic operations would be worsened if the buffer (with rumble strips) inhibits passing maneuvers or if passing zones are eliminated because of buffer painting. Again, experience is needed to see if this is a problem. Finally, Iowa has experienced some problems with vehicles using the buffer in preparation for turning left and being sideswiped by passing vehicles. Thus, left-turn lanes should be considered at intersections, and the design should be carefully studied if implemented in locations with high numbers of left turns into driveways. Since there is cost involved with both restriping and rumble strip placement, this measure may be more cost-effectively targeted to the "highest risk" locations rather than to large sections of the two-lane network. Otherwise, the benefits may not exceed the costs.
Appropriate Measures and Data	In program implementation evaluations, *process measures* include *number of road miles or number of hazardous locations* where buffer-medians are installed. They may include the aspect of exposure—*the number of vehicle miles of travel exposed to medians.* *Impact measures* will include the *number (or rate) of head-on crashes reduced* at these locations, along with any change in total crashes. The strategy will be most effective when a framework and a methodology exist to target the implementation to the most appropriate sites. This will require more detailed analysis of locations with excessive head-on crashes (rather than just total crashes).
Associated Needs	It would be expected that the driving public's view of this strategy would be similar to their view of centerline rumble strips. These may be viewed negatively by motorcyclists. Given the proposed width of the buffer median and the fact that it would include wider centerline rumble strips, it could also be viewed more negatively by the drivers of other vehicles. Thus, there would be the need for public information to

(*continued on next page*)

EXHIBIT V-7 (Continued)
Strategy Attributes for Reallocation of Total Width to Provide Median Buffer

	explain the function of the treatment in order to address any public concerns or potential misunderstanding.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	These strategies will be implemented by state and local roadway agencies, and it does not appear that extra coordination with other agencies or groups is needed. Implementing this policy will in many cases run counter to DOT design policy. Conventional thinking that is institutionalized in design policy is that wide lanes are safer and thus preferred over narrow lanes. Narrow lanes are normally considered as design exceptions and avoided. The design exceptions process is rigorously followed in most states and is driven in part by safety concerns and risk management involving potential tort claim actions. Other related policy issues include the established relationship between lane width and capacity, and state policies emphasizing provision for minimum levels of service. Acceptance and widespread implementation of this strategy will in many cases occur only with revision to a state's design policy. Acceptance of such a policy change is most likely if the safety benefits are clearly understood and articulated. It would seem that an effective design policy would promote this design treatment for specific, limited circumstances related to the safety concerns of head-on crashes and need for speed reductions. On a more positive note, there is growing concern and interest in design measures to proactively reduce speeds for certain conditions. Examples may include roadway approaches to small towns or through rural communities. Design agencies thus are beginning to show an interest in measures that effectively reduce speed without changing the fundamental character of the highway.
Issues Affecting Implementation Time	This low-cost strategy does not involve reconstruction, the environmental process, or ROW acquisition. Restriping can be accomplished quickly, but widening of paved shoulders would take longer.
Costs Involved	Costs will vary depending on whether the strategy is implemented as a stand-alone project or whether it is incorporated as part of a reconstruction or resurfacing effort already programmed. Including the necessary striping and rumble strips as part of a resurfacing project offers the opportunity for lowest cost implementation. In Pennsylvania, the cost to install rumble strips is about $2 a foot ($10,000 a mile), including traffic control while installing. If the strip pattern used in these buffer-medians is wider than the normal centerline rumble strip, then the cost will increase. It also will be increased by the cost of lane restriping.
Training and Other Personnel Needs	There appear to be no special personnel needs for implementing this strategy. States would use either agency personnel or contractors. However, training of state safety and design engineers on the attributes, benefits, and applicability of this treatment would be necessary. Conventional wisdom is that wider lanes are safer, hence overcoming initial skepticism toward a safety improvement that narrow lanes will require special training. Training regarding actual installation of rumble strips accompanying the median buffer will depend on whether the agency has been using retrofitted rumble strips on freeways or other roadways. If not, either agency personnel or contractor personnel will need to be trained in proper installation techniques.
Legislative Needs	None identified.
Other Key Attributes	
None Identified	

Information on Agencies or Organizations Currently Implementing this Strategy

The DOTs in Iowa, Pennsylvania, and Maryland have implemented this or similar strategies on certain roadway segments. As noted above, Iowa noted some sideswipe problems due to vehicles using the median to stop while turning left (perhaps converting some rear-end collisions to sideswipes) and noted the need for careful transition design to left-turn lanes at intersections. This strategy appears to be similar to a treatment used by Pennsylvania on a 6-mile section of Route 322 in 1993. There, both centerline rumble strips and a narrow "buffer-median" were installed, and in the 6 years since installation, there have been no fatal accidents. Maryland DOT implemented a narrow (4–10 ft) buffer median with median guardrail on two limited-access, two-lane routes (MD 140 and MD 90). Limited before/after results indicated large reductions in head-on and other crash types. More information on Maryland's program can be found in Appendix 1.

Objective 18.1 B—Minimize the Likelihood of Crashing into an Oncoming Vehicle

Strategy 18.1 B1—Alternating Passing Lanes or Four-Lane Sections at Key Locations

General Description

This strategy involves improving two-lane locations that experience many passing-related collisions. It involves constructing either alternating passing lanes or short four-lane sections that allow passing for both flows. While the treatment is designed to reduce passing-related, head-on crashes (a relative low percentage of all head-on crashes), it should also positively affect nonpassing head-on collisions at the treated sections since the passing lanes would provide extra "clear zone" for vehicles inadvertently leaving their through lanes. It may also affect other types of crashes such as rear-end crashes involving a turning vehicle, since the passing lane provides some protection for the left-turning vehicle.

This strategy would be more expensive and take longer to construct since it requires lane construction and would usually require additional right-of-way. However, it is less expensive than full-scale realignment or reconstruction and thus would appear to fit within AASHTO's current framework for this effort.

The construction of passing lanes would be compatible with the other head-on and ROR strategies. They would not be feasible for routes with narrow right-of-way where additional right-of-way cannot be purchased or is too expensive. This strategy may also be compatible with aggressive driving strategies such as mitigating congestion and minimizing frustration with drivers wanting but unable to execute passing maneuvers.

This strategy, although fairly widely used, has not been sufficiently evaluated to be considered "proven."

EXHIBIT V-8
Strategy Attributes for Providing Alternating Passing Zones on Two-Lane Highways (T)

Technical Attributes

Target

(1) Vehicles involved in head-on collisions on undivided two-lane roads during passing maneuvers. (2) Vehicles involved in nonpassing head-on crashes.

Expected Effectiveness

Based upon work by Harwood and St. John (1984), Rinde (1977), and Nettleblad (1979), as reviewed by the expert panel that developed two-lane Accident Modification Factors for the Interactive Highway Safety Design Model, a one-way passing lane could reduce total (not just head-on) crashes by 25 percent for the length of the installation. Based upon the same review by Harwood and St. John, the short four-lane sections allowing passing in both directions simultaneously are estimated to reduce total crashes by 35 percent for the length of the passing zone. It is noted that both of these estimates may be somewhat inflated since the effect of simultaneous shoulder treatments could not be completely removed in the effectiveness evaluation.

NCHRP Report 440 summarizes the result of a study that examined how sections of roadway treated with passing improvements compared with untreated sections (Fitzpatrick et al., 2000). The results, shown below, are for two-lane roads in rural or suburban areas and the reductions range from 25 percent to 40 percent. However, the report cautions that readers should use engineering judgment regarding the crash effects of these alternatives because crash experience varies greatly depending upon specific traffic and site characteristics.

Percent Reduction in Crashes for Four Design Alternatives

	Type of Crash	
Design Alternative	**Total Crashes**	**Fatal and Injury Crashes**
Passing lanes	25	30
Short four-lane section	35	40
Turnouts	30	40
Shoulder use section	*	*

* No known significant effect.

Passing lanes are known to have traffic operational effects that extend 5 to 13 km (3 to 8 miles) downstream of the passing lane. It might be presumed that these operational effects provide analogous safety benefits over a similar length of highway. However, since this effect has not been quantified, it is not included in the estimate.

It is important to carefully consider the cautions given in each of the studies cited above. Although these studies seem to indicate a reduction in crashes, more analysis of such treatments is required before a statistically sound measure of the effectiveness can be developed. This treatment has not been sufficiently evaluated to be considered a proven strategy. However, there have also been no significant findings of negative effects of this strategy.

Keys to Success

The effectiveness of this strategy would be maximized on routes with significant unmet demand for safe passing. This would include routes with a range of driving speeds (e.g., hilly terrain with significant truck traffic) and a horizontal and vertical

EXHIBIT V-8 (Continued)
Strategy Attributes for Providing Alternating Passing Zones on Two-Lane Highways (T)

	alignment providing few safe-passing opportunities. Thus, one key to success is the agency's ability to identify these locations.
Potential Difficulties	This strategy would require significant construction and may involve right-of-way costs. Some states that have implemented three-lane passing sections (i.e., a passing lane in one direction) have noted a potential problem with downhill passing across the yellow "no passing" centerline. This occurs when a vehicle in the no-passing, downhill flow can see a safe passing gap and passes across the "no-passing" centerline. Pennsylvania notes that in some states, there is an enforcement issue in that the police may not consider crossing the double-yellow centerline as sufficient proof of an infraction. In addition, some states allow this passing maneuver legally. It can lead to driver confusion. State DOT staff interviewed indicated that they did not feel that allowing such passing was a good idea. The Michigan DOT is currently adding a fourth lane to downhill sections that have a passing lane for one direction to eliminate the potential problem. Minnesota has implemented some short four-lane passing sections and has noted some problems with left-turning traffic at intersections. Minnesota DOT staff suggests transitioning the four-lane sections back to two-lanes prior to an intersection and possibly implementing a left-turn lane at the intersection.
Appropriate Measures and Data	In implementation evaluations, *process measures* would include the *number of road miles, or number of hazardous locations,* where such passing zones are constructed. *Impact measures* would include the *number of head-on and total crashes reduced* at these locations. Traffic operations data and crash information will be needed to define sections with unmet safe-passing demand.
Associated Needs	Unless this is a new treatment in a given state, there should not be significant public "training" needs. However, since the public assumes that conversion to a multilane configuration is always better, a public information program explaining the benefits and relative costs of this treatment could be helpful in selling the implementation.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	These strategies will be implemented by state and local roadway agencies, and it does not appear that extra coordination with other agencies or groups is needed. No new policy efforts are required.
Issues Affecting Implementation Time	Since this would require reconstruction (and usually right-of-way acquisition), the time required would be longer than for other less-involved strategies.
Costs Involved	The costs involved would depend on the number and length of locations treated and whether right-of-way must be purchased. In general, this strategy would be significantly more costly than some others (e.g., rumble strips, marking and delineation), but less costly than conversion to four lanes, or to a Super Two design.
Training and Other Personnel Needs	There appear to be no special personnel needs for implementing this strategy, since state or contractor personnel would implement it. Since this treatment is not new, it should not require significant training other than providing information to design and construction engineers concerning the benefits of the treatment.
Legislative Needs	None identified.
Other Key Attributes	
None Identified	

Information on Agencies or Organizations Currently Implementing this Strategy

A number of states have employed passing lanes. More specifically, both the Washington and Pennsylvania DOTs have implemented passing lanes and wider shoulders to allow passing at certain locations. Michigan has added passing and climbing lanes to increase capacity (rather than as a safety treatment) for a number of years. Because of the earlier noted potential problem with downhill passing across the yellow “no-passing” centerline, Michigan is currently adding a fourth lane to downhill sections that have a passing lane for one direction. Therefore, Michigan can provide guidelines on these installations. Minnesota has installed some short four-lane passing sections, and it can provide guidelines on the length of the passing lanes based on AASHTO information.

Strategy 18.1 B2—Median Barriers for Narrow Medians on Multilane Roads

General Description

This strategy involves providing barriers on multilane roads with narrow or no medians. Barriers can be rigid (e.g., concrete median barrier, guardrail) or semi-rigid (e.g., cable barrier). The treatment would be designed to prevent head-on collisions from occurring. The treatment is also used on high-speed, two-lane roads during construction (e.g., during freeway reconstruction, both directions of traffic are often shifted to one roadway, with temporary barriers provided between the opposing traffic).

EXHIBIT V-9
Median Barrier Application in Massachusetts

The strategy is primarily applicable in the rural or outlying suburban environment where speeds are higher and the need for median openings for intersections and driveways are less than in urban areas. Arterials, expressways, and full freeways are candidates for treatment.

The strategy would apply to roadways that may have experienced significant traffic growth and increased serious crashes since original construction. In many cases, original design assumptions on speed and traffic demands resulted in decisions to forego median barriers.

Finally, this design may be incompatible with other strategies designed to minimize ROR crashes. A continuous median barrier is itself a potential hazard. As many as 30 percent of high-speed barrier impacts produce injuries and fatalities.

This strategy, although fairly widely used, has not been sufficiently evaluated to be considered “proven.”

EXHIBIT V-10
Strategy Attributes for Providing Median Barriers on Multilane Roads (T)

Technical Attributes

Target	Drivers of vehicles who unintentionally cross the centerline.

Expected Effectiveness

There are various studies that describe the crashworthiness of a number of different median barriers. The points below summarize the quantitative results for two studies identified in *NCHRP Synthesis of Highway Practice 244* (Ray and McGinnis, 1997).

- A study performed in the late 1960s using New York data found that the injury and fatality rate for weak-post barriers was 10 percent versus the 20 percent rate for strong-post barriers.
- The results below evaluate the performance of median barriers using Longitudinal Barrier Special Studies (LBSS) data. The findings support conventional wisdom that the barriers that allow more lateral deflection result in less severe collisions. However, the percentage of vehicles being redirected, snagging, or penetrating increases with the weak-post system.

Strategy Attributes for Providing Median Barriers on Multilane Roads

	Median Barrier Type			
	Weak-Post	**Strong-Post**	**Concrete**	**Other**
Injury or Fatality (%)	8.8	17.5	16.2	11.5
Redirect (%)	82	88	91	78
Snag (%)	12	5	0	7
Penetrate (%)	3	5	5	15

The statistics listed above highlight a few types of median barriers but do not give insight regarding the safety of a roadway with and without a median barrier. Statistically sound studies are still needed to produce effectiveness measures and to consider this strategy a proven strategy. However, this strategy was tried and accepted in a number of applications. Additionally, there have been no significant findings that the effects of striking the barrier will have a worse result than the head-on collision it is designed to prevent.

Keys to Success

Initial keys to success would be experimental use and careful evaluation to determine effectiveness, cost, and adverse consequences. If effective, effort will be directed at identifying the characteristics of the roadway (traffic volume, speed, alignment quality, cross section) for which median barriers may be expected to have the greatest net positive effect. In addition, many barriers require clear area behind the rail for deflection. If this alternative is to address narrow medians, then careful consideration must be made to ensure that the median barrier installed has the necessary clear area. *NCHRP Synthesis of Highway Practice 244* reports that weak-post cable barriers require about 11 ft (3.3 m) behind the rail. Such a requirement limits the use of this barrier on narrow median roadways.

Potential Difficulties

Many states are reluctant to implement barriers given the uncertain net safety performance and maintenance problems created. In some cases, implementation of

(*continued on next page*)

EXHIBIT V-10 (Continued)
Strategy Attributes for Providing Median Barriers on Multilane Roads (T)

	concrete barriers would require closing up of the median and construction of expensive closed drainage systems. Less expensive cable barrier systems also are viewed as requiring high levels of maintenance. DOT staff from both Michigan and Minnesota has expressed some concern with possible end treatments at intersections—i.e., what attenuator can be used in these narrow medians. Minnesota also identified some potential problems with sight distance decreases at intersections due to the presence of the barrier. Finally, barriers in northern climates present snow removal and storage problems, particularly where medians are narrow.
Appropriate Measures and Data	In implementation evaluations, *process measures* include *number of road miles* or *number of hazardous locations* where median barriers are installed. They may include the aspect of exposure—the *number of vehicle miles of travel exposed to medians.* Impact measures will include the *number (or rate) of head-on crashes reduced* at these locations, along with any change in total crashes. The strategy will be most effective when data and an analysis methodology exist to target the implementation to the most appropriate sites—a methodology that identifies sites based on head-on rather than total crashes.
Associated Needs	There do not appear to be any special needs. There should not be a need for any public information and education, since the motoring public is familiar with median barriers.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	These strategies will be implemented by state and local roadway agencies, and it does not appear that extra coordination with other agencies or groups is needed. If the state does not have a policy defining median width and/or traffic characteristics where barriers are to be installed, one may be needed. Most states use median barrier warrants similar to those published in AASHTO's *Roadside Design Guide.* Such warrants may need to be adjusted or refined.
Issues Affecting Implementation Time	This moderate cost strategy would in many cases be readily implementable within a 1-to 3-year period after site selection. Barrier design and placement within existing narrow medians would require no right-of-way, a minimal environmental process, and generally one construction season.
Costs Involved	Costs will vary depending on whether the strategy is implemented as a stand-alone project or whether it is incorporated as part of a reconstruction or resurfacing effort already programmed. However, *NCHRP Synthesis of Highway Practice 244* summarized survey results of 39 states to quantify the typical installation cost for roadside and median barriers (Ray and McGinnis, 1997). See Appendix 9. When evaluating the cost-effectiveness of a particular type of median barrier, it may be more appropriate to consider the life-cycle cost of the barrier. This takes into account both the life span and the expected maintenance cost of the barrier. Both of these items are important considerations in overall cost-effectiveness.
Training and Other Personnel Needs	There appear to be no special personnel or training needs for implementing this strategy, assuming that an agency deploys its standard barrier treatments. States would either use agency personnel or contractors.
Legislative Needs	None identified.
Other Key Attributes	
None Identified	

Information on Agencies or Organizations Currently Implementing this Strategy

State DOTs currently using or exploring this strategy include Minnesota, Washington, Pennsylvania, Maryland, Michigan, Massachusetts, and Iowa. In addition, the city of Seattle, Washington, has installed movable median barriers in very narrow medians to reduce head-on crashes. Seattle chose the movable barrier because of the barrier's narrow footprint. A number of states, including California and Michigan, are conducting studies and implementing median barrier projects on high-volume roads. Indications from the work in California are that barriers appear to be warranted at greater median widths than where used previously, suggesting that the magnitude of the utility of this strategy may be significant.

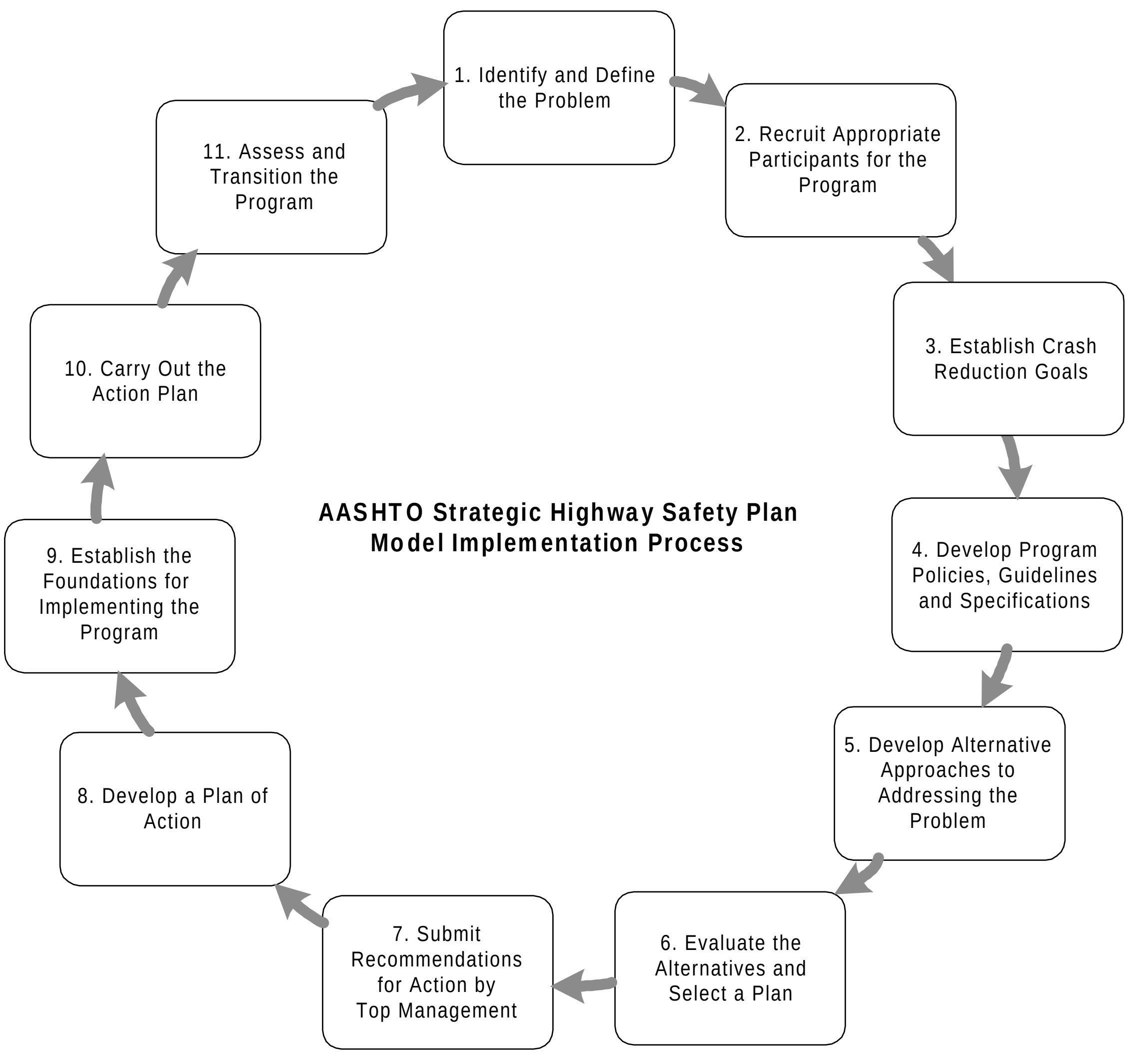
SECTION VI

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

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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
vpd	Vehicles Per Day	
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 Profiles of State and Local Implementation Efforts: Strategies 18.1 A1 and 18.1 B2 (Maryland State Highway Administration)
2 Profiles of State and Local Implementation Efforts: Strategy 18.1 A1 (Virginia Department of Transportation)
3 Profiles of State and Local Implementation Efforts: Strategy 18.1 A1 (Kansas Department of Transportation)
4 Profiled Thermoplastic Stripes for Centerline, Texas DOT
5 Profiles of State and Local Implementation Efforts: Strategy 18.1 A3 (Washington Department of Transportation)
6 Profiles of State and Local Implementation Efforts: Strategy 18.1 A3 (Iowa Department of Transportation)
7 Profiles of State and Local Implementation Efforts: Strategy 18.1 A3 (Minnesota Department of Transportation)
8 Profiles of State and Local Implementation Efforts: Strategy 18.1 A2 (California Department of Transportation)
9 Cost of Median Barriers
10 Cost of Profile Thermoplastic Striping
11 Costs for Centerline Rumble Strips
12 Candidate Types of Stakeholders for Involvement in Planning and Implementing Programs to Mitigate Head-on Crashes

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

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