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84 pages | | PAPERBACK

ISBN 978-0-309-43595-6 | DOI 10.17226/23088

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NCHRP REPORT 500

**Guidance for Implementation of the
AASHTO Strategic Highway Safety Plan**

*Volume 20: A Guide for
Reducing Head-On
Crashes on Freeways*

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Safety and Human Performance

Research sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.

2008

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NCHRP REPORT 500, VOLUME 20

Project 17-18(3)

ISSN 0077-5614

ISBN: 978-0-309-09936-3

Library of Congress Control Number 2008904443

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are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:

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Printed in the United States of America

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FOREWORD

By Charles W. Niessner

Staff Officer

Transportation Research Board

The American Association of State Highway and Transportation Officials (AASHTO) has adopted a national highway safety goal of halving fatalities over the next 2 decades—or reducing the number of fatalities by 1,000 per year. 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 twentieth volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* provides strategies that can be employed to reduce head-on crashes on freeways. 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. 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 twentieth 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://safety.transportation.org>. 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.

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ACKNOWLEDGMENTS

This volume of *NCHRP Report 500* was developed under NCHRP Project 17-18(3), the product of which is a series of implementation guides addressing the emphasis areas of AASHTO's Strategic Highway Safety Plan. The project was managed by CH2M Hill. Timothy Neuman of CH2M Hill served as the overall project director for the team. Kelly Hardy, also of CH2M Hill, served as a technical specialist on the development of the guides.

The project team was organized around the specialized technical content contained in each guide, and the team included nationally recognized experts from many organizations. The following team of experts, selected based on their knowledge and expertise in this particular emphasis area, served as lead authors for the Head-on guide:

- John Nitzel
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- Nick Antonucci
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Development of the volumes of *NCHRP Report 500* 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 documents represent best practices in each emphasis area. The project team is grateful to the following list people and their agencies for supporting the project through their participation in workshops and meetings, as well as additional reviews of the Head-on guide:

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Summary

Introduction

Head-on crashes that occur on freeways are typically severe in nature and may be on the increase. A head-on crash typically occurs when a vehicle crosses the median and crashes with a vehicle traveling in the opposite direction (typically called a cross-median crash or median-crossover crash). A head-on crash can also occur when a vehicle inadvertently travels the wrong way in the opposing traffic lanes. Head-on cross-median crashes are typically the result of inadvertent actions by a driver potentially in combination with other adverse circumstances such as weather conditions or motorist fatigue.

Recent experience and research has shown that a comprehensive approach to safety is most effective in creating a safer driving environment and improved effectiveness of safety treatments. A number of safety concerns including many related to head-on crashes cannot be as effectively solved by solely applying one of the “four E’s” (engineering, education, enforcement, and emergency medical services) in isolation. When reviewing strategies dealing with head-on crashes, engineers should strongly consider the role of the other “four E” groups. To address the importance of considering a “four E” approach this document provides strategies that might be considered.

General Description of the Problem

In 2003, according to the FARS statistics, there were 366 fatal cross-median head-on crashes on U.S. freeways. In 2003 the total number of fatal crashes on Interstate routes was 4,813 with cross-median crashes representing almost 8 percent of the total. Although the number may seem small when compared to the number of overall crashes and to the percentage of all Interstate-related crashes, head-on crashes are extremely severe. This is illustrated by a recent study from the FHWA which considered the number of crossover fatalities on freeways on a national basis. From 1994 to 2002, while fluctuating annually, median-crossover and wrong-way fatalities have increased by 17 percent (Ostensen, 2004). FHWA, in the memo, characterizes this increase as—“In many states, population growth in and around metropolitan areas has resulted in an increase in the vehicle-miles of travel and lane density, factors that may account for an increase in cross-median crashes on freeways approaching or circumventing urban areas. Nationally, the number of crossover fatalities on freeways, while fluctuating, has steadily increased from 581 in 1994 to 680 in 2002.” In addition, it appears that a number of cross-median fatal crashes may have occurred at locations where some type of barrier was in place.

Programs and Strategies

Objectives

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

- Keep vehicles from departing the traveled way
- Minimize the likelihood of head-on crashes with an oncoming vehicle

- Reduce the severity of median-barrier crashes that occur
- Enhance enforcement and awareness of traffic regulations
- Improve coordination of agency safety initiatives

These objectives are similar to those cited for run-off-road crashes (emphasis area 15, Volume 6 of this guide) and head-on collisions (emphasis area 18.1, Volume 4 of this guide). Exhibit I-1 summarizes the objectives and strategies.

For each objective identified (except for the last objective), there exist various strategies as listed in Exhibit I-1 below. Each strategy is described in detail in this guide.

EXHIBIT I-1

Objectives and Strategies for Addressing Head-On Crashes on Freeways

Objectives	Strategies
18.2 A Keep vehicles from departing the traveled way	18.2 A1 Install left shoulder rumble-strips 18.2 A2 Provide enhanced pavement markings and median delineation 18.2 A3 Provide improved pavement surfaces
18.2 B Minimize the likelihood of head-on crashes with an oncoming vehicle	18.2 B1 Provide wider medians 18.2 B2 Improve median design for vehicle recovery - Pavement edge drop-offs - Install paved median shoulder - Design for safer slopes 18.2 B3 Install median barriers for narrow-width medians 18.2 B4 Implement channelization, signing and striping improvements at interchanges susceptible to wrong-way movements
18.2 C Reduce the severity of median barrier crashes that occur	18.2 C1 Improve design and application of barrier and attenuation systems
18.2 D Enhance enforcement and awareness of traffic regulations	18.2 D1 Designate “Highway Safety Corridors” 18.2 D2 Conduct public information & education campaigns
18.2 E Improve coordination of agency safety initiatives	18.2 E1 Enhance agency crash data systems

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 of the Strategic Safety Plan 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 four emphasis areas:

- Run-off-road (ROR) crashes
- Head-on collisions
- Head-on collisions on freeways
- Crashes with 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 freeways and expressways that have full access control. A head-on crash typically occurs when a vehicle crosses the median and crashes with a vehicle traveling in the opposite direction (typically called a cross-median crash or median-crossover crash). A head-on crash can also occur when a vehicle inadvertently travels the wrong way in the opposing traffic lanes. In either event, such crashes are inherently severe. Head-on cross-median crashes may be the result of inadvertent actions by a driver and potentially in combination with other adverse circumstances such as weather conditions or motorist fatigue.

One of the goals of the AASHTO Strategic Highway Safety Plan is to consider safety problems in a comprehensive manner, both in the range of objectives and in strategies developed. The various strategies described in these guides will cover various elements of the transportation system: the driver, the vehicle, the highway, emergency medical services, and the management system.

An overall goal is to move away from *independent* activities of engineers, law enforcement officials, educators, judges, and other highway safety specialists to coordinated efforts. The implementation process outlined in the guides promotes the formation of working groups and alliances that represent the elements of the safety system. The working groups and alliances 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.

Type of Problem Being Addressed

General Description of the Problem

In 2003, according to the FARS statistics, there were 366 fatal cross-median head-on crashes on U.S. freeways. Although the number may seem small when compared to the number of overall crashes and to the percentage of all Interstate-related crashes—6 percent—head-on crashes are extremely severe.

Data from the FHWA considered the number of fatalities on a national basis. From 1994 to 2002, while fluctuating on an annual basis, median-crossover and wrong-way fatalities on divided highways have increased from 581 to 680 (Ostensen, 2004).

The National Highway Transportation Safety Administration (NHTSA) defines a head-on collision as one where the front end of one vehicle collides with the front end of another vehicle while the two vehicles are traveling in opposite directions. For this guide, we are considering only head-on crashes occurring on Interstates and other freeways or expressways.

From the FARS database there is no identifiable pattern for these crashes, other than their occurrence on freeways with open medians. North Carolina research showed that head-on collisions take place at all times, days, and seasons, and on horizontal and vertical curves as well as straight and flat sections. There is no predominant cause. Driver behavior is clearly important, including everything from fatigue and improper lane changes to inattention and medical emergencies.

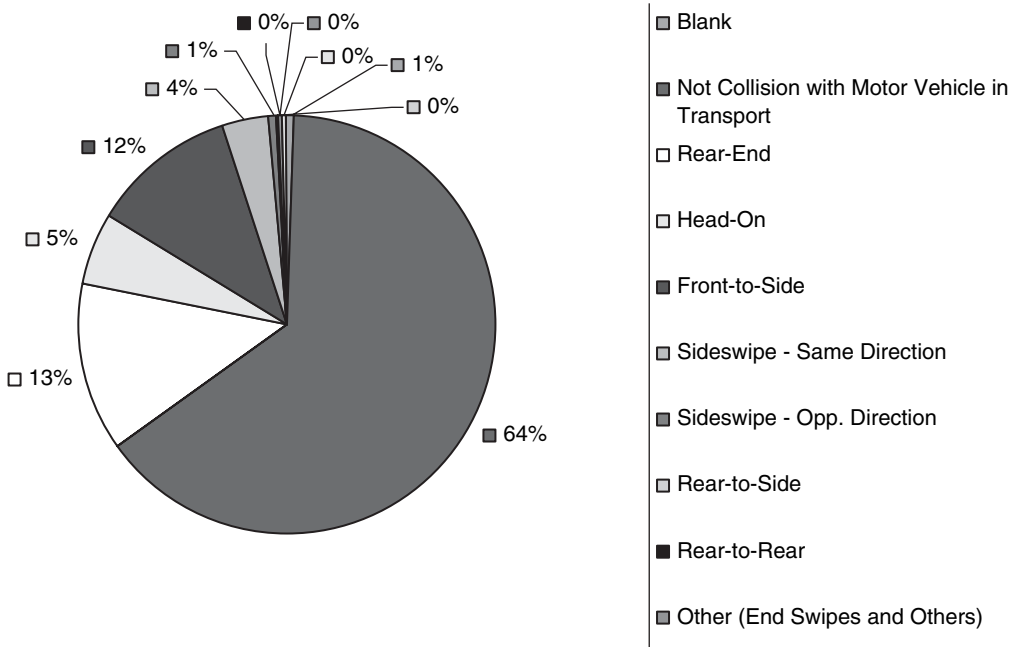
Specific Attributes of the Problem

Donnell et al. (2002) show that the major contributory factors for median-barrier crashes occurring on Pennsylvania Interstate highways were improper lane changes, driver losing control of vehicle, traveling too fast for weather conditions, exceeding the posted speed limit, and forced vehicle movement or avoidance maneuvers.

Exhibit III-1 shows the distribution of fatal crashes for Interstate freeways for 2003. Five percent of the crashes were head-on, and 1 percent was opposite-direction sideswipes. A study in Iowa showed that between 1990 and 1999, though only 2.4 percent of all Interstate crashes were cross-median, they produced 32.7 percent of all the Interstate fatalities during that period. A study by the North Carolina Department of Transportation (NCDOT) in 1998 showed that more than 38 people died and about 300 were injured in cross-median crashes each year (Lynch, 1998). The Florida Department of Transportation found in an unpublished preliminary study that is still underway that 62 percent of all cross-median crashes occurred within $\frac{1}{2}$ mile and 82 percent occurred within 1 mile of interchange ramp termini (Bane, 2005).

Exhibit III-2 shows that, according to 2003 FARS data, 56 percent of these crashes occur on urban Interstates/freeways and 44 percent occur on rural Interstates. Exhibit III-3 shows

EXHIBIT III-1
 Fatal Crashes by Manner of Collision on Interstates
 Source: 2003 FARS data.



that, based on 2005 FARS data, over the years since 1994 urban sections of Interstates have consistently experienced a greater proportion of fatal crashes than those in rural areas.

As Exhibit III-4 indicates, 65 percent of those involved in the crossover crashes are male. Individuals in the 15–25 age group make up a large number of those involved in head-on crashes, and the number of head-on crashes per age group declines with increasing age. A study of median crashes for Wisconsin showed that the largest bracket of drivers involved was the 20- to 24-year-old range (McKendry and Noyce, 2005). The percentage generally decreased as the driver age increased. Exhibit III-5 shows the breakdown of fatal crashes by light condition. About 43 percent of crashes occur during the daytime and 54 percent at night, but of those occurring at night, nearly one-half occur on lighted roadways.

FARS data are consistent with studies in individual states. A publication from FHWA’s Office of Safety, “Median Barriers,” indicates the following summary statistics (Powers, 2007):

EXHIBIT III-2
 Head-on Crashes on Interstates, Urban vs. Rural
 Source: 2003 FARS data.

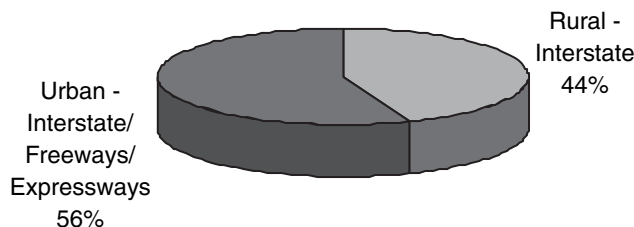
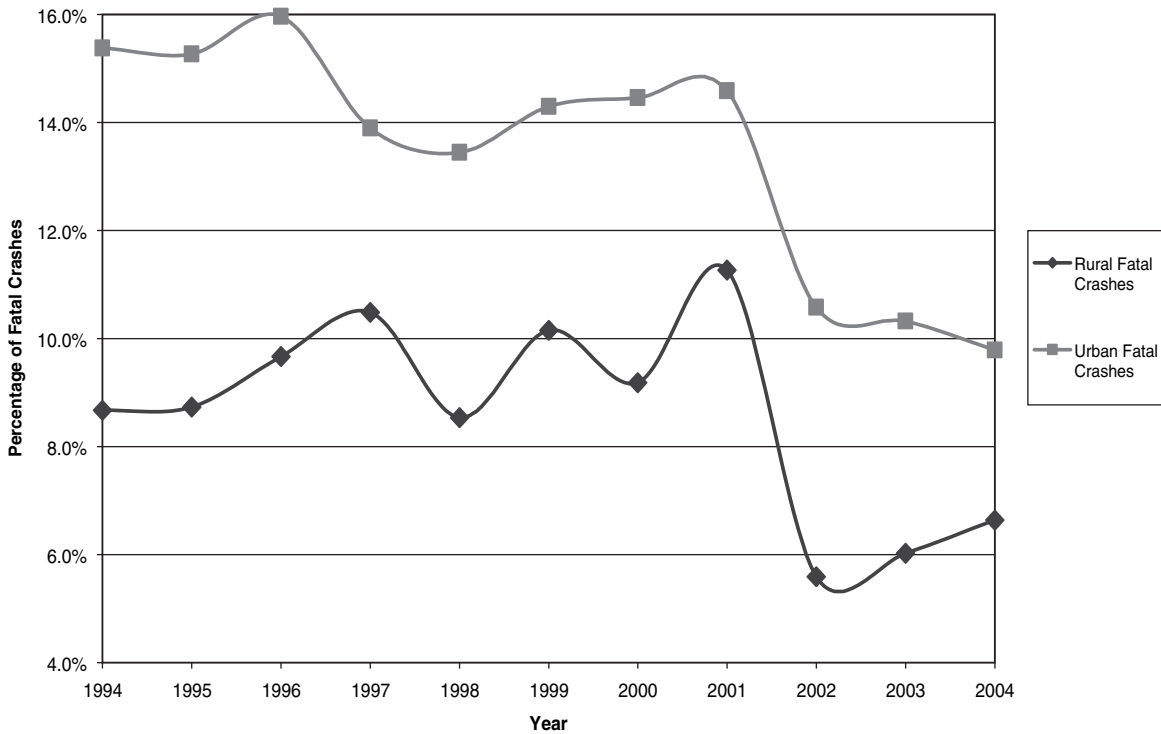


EXHIBIT III-3

Percentage of Fatal Crashes on Interstate Highways that are Head On or Sideswipe Opposite Direction
Source: 2005 FARS data.



- There is one crossover fatality annually for about every 200 freeway miles
- An average of 250 people are killed annually in freeway crossover crashes
- Median crashes are three times more severe than other highway crashes (Stasberg and Crawley, 2005)

EXHIBIT III-4

Fatal Crossover Crashes on Interstates by Gender
Source: 2003 FARS data.

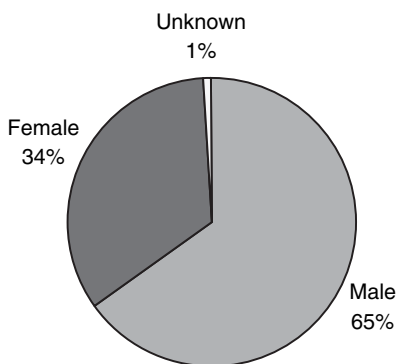
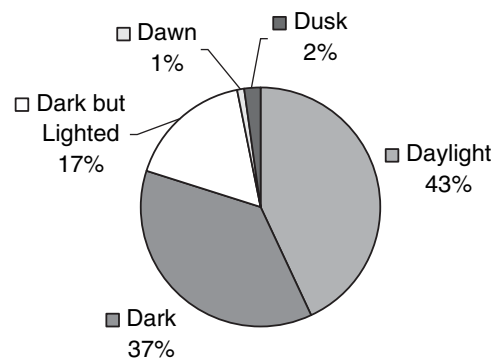


EXHIBIT III-5

Fatal Crossover Crashes on Interstates by Light Condition
Source: 2003 FARS data.



Mason et al. (2001) used crash and roadway inventory data to characterize cross-median crashes on Pennsylvania Interstates and expressways. Of the cross-median crashes, 15 percent were fatal and 72 percent resulted in occupants being injured. When compared to all crash types on Interstates and expressways, the severity level of cross-median crashes was significantly higher.

As Exhibit III-5 indicates, 37 percent of the fatal crossover crashes occur during conditions of darkness.

Summary

Although a relatively small proportion of total fatalities, according to FHWA data head-on crashes on freeways and Interstates appear to be increasing in recent years. Head-on crashes can occur under a wide range of circumstances. The predominant geometric feature associated with such crashes is the median, including its width as well as the presence (or absence) of a barrier or similar device, and proximity to interchanges. There is evidence that such crashes are associated with high-risk driver behaviors, including excessive speeding and erratic maneuvers.

SECTION IV

Index of Strategies by Implementation Timeframe and Relative Cost

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

EXHIBIT IV-1

Strategies Classified by Relative Cost and Time Necessary for Implementation

Relative Cost to Implement and Operate	Strategy
<i>Time Frame: Short (less than a year)</i>	
Low	18.2.A1—Install Left Shoulder Rumble Strips
	18.2.A2—Provide Enhanced Pavement Markings and Median Delineation
	18.2.D1—Designate “Highway Safety Corridors”
Moderate	18.2.D2—Conduct Public Information and Education Campaigns
Moderate to High	
High	
<i>Time Frame: Medium (1–2 years)</i>	
Low	
Moderate	18.2.A3—Provide Improved Pavement Surfaces
	18.2.B4—Implement Channelization, Signing and Striping Improvements at Interchanges Susceptible to Wrong-Way Movements
	18.2.E1—Enhance Agency Crash Data Systems
Moderate to High	18.2.B2—Improve Median Design for Vehicle Recovery
	18.2.C1—Improve Design and Application of Barrier and Attenuation Systems
High	
<i>Time Frame: Long (more than 2 years)</i>	
Low	
Moderate	18.2.B3—Install Median Barriers for Narrow-Width Medians
Moderate to High	
High	18.2.B1—Provide Wider Medians

Description of Strategies

Objectives of the Emphasis Area

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

- Keep vehicles from departing the traveled way
- Minimize the likelihood of head-on crashes with an oncoming vehicle
- Reduce the severity of median barrier crashes that occur
- Enhance enforcement and awareness of traffic regulations
- Improve coordination of agency safety initiatives

These objectives are similar to those cited for run-off-road crashes (emphasis area 15.1, Volume 6 of this guide) and head-on collisions (emphasis area 18.1, Volume 4 of this guide). Exhibit V-1 summarizes the objectives and strategies.

EXHIBIT V-1

Objectives and Strategies for Addressing Head-On Crashes on Freeways

Objectives	Strategies
18.1 A Keep vehicles from departing the traveled way	18.2 A1 Install left shoulder rumble strips (T)
	18.2 A2 Provide enhanced pavement markings and median delineation (T)
	18.2 A3 Provide improved pavement surfaces (T)
18.1B Minimize the likelihood of head-on crashes with an oncoming vehicle	18.2 B1 Provide wider medians (P)
	18.2 B2 Improve median design for vehicle recovery (T)
	—Pavement edge drop-offs —Install paved median shoulder (new) —Design for safer slopes
	18.2 B3 Install median barriers for narrow-width medians (P)
18.1 C Reduce the severity of median barrier crashes that occur	18.2 B4 Implement channelization, signing and striping improvements at interchanges susceptible to wrong-way movements (T,E)
	18.2 C1 Improve design and application of barrier and attenuation systems (T)
18.1 D Enhance enforcement and awareness of traffic regulations	D1 Designate “Highway Safety Corridors” (T)
	D2 Conduct public information & education campaigns (T)
18.1 E Improve coordination of agency safety initiatives	E1 Enhance agency crash data systems (T)

P = proven; T = tried; E = experimental. Several strategies have sub-strategies with different ratings.

Types of Strategies

The strategies in this guide were adopted from a number of sources, including recent literature, contact with state and local agencies throughout the United States, and federal programs. Some of the strategies are widely used, while others are used at a state or local level in limited areas. Some have been subjected to well-designed evaluations to prove their effectiveness. On the other hand, 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 assist the reader, the strategies have been classified into three types, each identified by letter symbol throughout the guide:

- **Proven (P):** Those strategies that have been used in one or more locations and for which properly designed evaluations have been conducted which show them to be effective. These strategies may be employed with a good degree of confidence, with the understanding that any application can lead to results that vary significantly from those found in previous evaluations. The attributes of the strategies that are provided will help the user make judgments about which ones may be the most appropriate for their particular situation(s).
- **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 continue under the AASHTO Strategic Highway Safety Plan (SHSP) initiative, appropriate evaluations will be conducted. As more reliable effectiveness information is accumulated to provide better estimating power for the user, any given strategy labeled “tried” can be upgraded to a “proven” one.
- **Experimental (E):** Those strategies representing ideas that have been suggested, with at least one agency considering them sufficiently promising to try them as an experiment in at least one location. These strategies should be considered only after the others have proven not to be appropriate or feasible. Even when 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 or identified as being ineffective and not worthy of further consideration.

Related Strategies for Creating a Truly Comprehensive Approach

The strategies listed above, and described below in detail, are those considered unique to this emphasis area. However, to create a truly comprehensive approach to highway safety issues and problems associated with this emphasis area, there are related strategies recommended as candidates for possible inclusion in any program-planning process related to addressing head-on crashes for freeways. 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, in some instances it may be desirable to focus on a location-specific problem. While this is a relatively untried strategy compared with area-wide campaigns, use of roadside signs or other experimental approaches may be tried on a pilot basis.

Within the context of this guide, a PI&E effort is usually used in support of another strategy. In such a case, the description for that strategy will suggest the use of this approach (see the attribute area for each strategy entitled, “Associated Needs for, or Relation to, Support Services”). In some instances, specialized PI&E campaigns are deemed appropriate for the emphasis area and are explained in detail within the guide. When this occurs the appropriate links will be posted online on <http://transportation1.org/safetyplan>.

- **Strategies to Improve the Safety Management System**—The effective management of the highway safety system is fundamental to improving traffic safety. A sound organizational structure and an effective decision support system, as well as a set of appropriate laws and policies to monitor, control, direct and administer a comprehensive and strategic approach to highway safety are all necessary. It is important that a comprehensive program not be limited to one jurisdiction, such as a state DOT. Other agencies often oversee an important part of the safety system and they may know, better than others, about the most important issues and problems. As additional guides are completed for the AASHTO Strategic Highway Safety Plan, they may address additional details regarding the design and implementation of strategies for safety management systems. When that occurs, the appropriate links will be added from this emphasis area guide.
- **Strategies to Improve Emergency Medical and Trauma System Services**—Treatment of injured persons at crash sites can have a significant effect on injury severity and the duration of needed treatment. Thus, a basic part of a highway safety infrastructure is a comprehensive emergency care program. Although emergency services are often thought of as simply support services, they can be critical to the success of a comprehensive highway safety program. Therefore, an effort should be made to determine if there are improvements that can be made to this aspect of the system in the context of an identified strategy for this guide, especially for programs that are focused upon location-specific (e.g., corridors), or area-specific (e.g., rural areas) issues. *NCHRP Report 500, Volume 15: A Guide for Enhancing Rural Emergency Management Systems* covers one specific aspect of this.

- **Enforcement of Traffic Safety Laws**—Well-designed, well-operated law enforcement programs can have a significant effect on highway safety and must be an element in a strategic and comprehensive highway safety program. It is well established, for example, that an effective way to reduce crashes (and their severity) resulting from driving under the influence (DUI) is to have jurisdiction-wide programs that enforce effective laws against such behavior. When these laws are vigorously enforced with well-trained officers, the frequency and severity of highway crashes can be significantly reduced.

Enforcement programs, by their nature, are conducted at specific locations. The effect (e.g., lower speeds, reduced impaired driving) may occur at or near the specific location where the enforcement occurs. This effect can often be enhanced by coordination of the effort with an appropriate PI&E campaign. However, the effect of enforcement efforts can be area-wide or jurisdiction-wide. The effect can be positive (i.e., the desired reductions occur over a greater part of the system) or negative (i.e., the problem moves to another location where enforcement is not conducted). In this guide, since enforcement programs are deemed potentially appropriate, at a minimum, as an experimental strategy for this emphasis area, the strategy is explained in detail as it relates to head-on crashes on freeways (see Objective 18.1 D).

- **Strategies That Are Detailed in Other Emphasis Area Guides**—Programs to improve safety related to head-on crashes for freeways should also consider applicable strategies covered in the following guides (<http://www.safety.transportation.org>):
 - Head-On Collisions
 - Horizontal Curves
 - Aggressive Driving
 - Speed Guide (under development)
 - Run-Off-Road Collisions
 - Rural Emergency Management Systems
 - Unbelted Occupants
 - Unlicensed Drivers
 - Distracted Fatigued Drivers
 - Alcohol Impaired Drivers
 - Safety Data Needs (under development)

Objective 18.2 A—Keeping Vehicles from Departing the Traveled Way

This objective assumes a vehicle has not left the road and is in the travel lanes or about to stray out of a lane into the median. The strategies presented involve either keeping the vehicle in a travel lane through enhanced traffic control devices that engage the driver's attention or by the installation of improved pavement capability to reduce skidding and reduce the potential of leaving the roadway. In addition, if a driver strays from the road, a strategy of providing left median shoulder rumble strips is suggested to give an audible alert to the driver so that it is possible to regain control.

Strategy 18.2 A1—Install Left Shoulder Rumble Strips (T)

The purpose of rumble strips is to alert drivers who may inadvertently stray or encroach into the median. Rumble strips help alert drowsy and inattentive drivers that they are about to cross the edge line into the shoulder. When driven over by a vehicle, they produce a sudden rumbling sound and cause the vehicle to vibrate, thereby alerting the driver.

Shoulder rumble strips are crosswise grooves in the road shoulder. States have developed various design dimensions, but generally they are about 0.5 inches deep, spaced about 7 inches apart, and cut in groups of four or five. They can be rolled into hot asphalt or concrete as it is laid, or they can be milled in later.

Rumble strips on Interstate highways are used extensively on right shoulders and increasingly on the left or median shoulder. There are four types of rumble strips: milled-in, rolled-in, formed, and raised. They primarily differ in type of installation, size and shape, and noise and vibration produced. While all four types of rumble strips are in use, recent experience from a number of states is that milled-in rumble strips are more frequently used as the response by motorists has been better relative to the rolled-in strip. To effectively install milled rumble strips it is important that the existing shoulder be in good condition.

Additional details concerning current practice with rumble strips can be found on FHWA’s “Rumble Strip Community of Practice” web page (<http://safety.fhwa.dot.gov/rumblestrips/>). This site provides definitions of types of rumble strips used, detailed construction drawings, effectiveness estimates, and interviews with users and other experts, among other information. Extensive information and details describing, for example, the four major types of rumble strips (milled, rolled, formed, and raised) are given on the FHWA web page. Also refer to the run-off-road guide (*NCHRP Report 500, Volume 6*) for more details on design and other features of rumble strips and to the FHWA Technical Advisory, T 5040.35 (FHWA, 2001).

Left (median) shoulder rumble strips are similar to those of right shoulder rumble strips. Right shoulder rumble strips have been tested for their effectiveness for the run-off-the-road crashes. Some of the factors associated with both crash types are similar, such as fatigue, distraction, drowsiness, and alcohol-drug impairment. However, when a vehicle runs off the road towards the left shoulder there is an increased probability of it being involved in cross-median collision. But it is not specifically known how effective this treatment would be for cross-median head-on crashes as there has not been a study which directly evaluates their effect.

EXHIBIT V-2

Strategy Attributes for Left Shoulder Rumble Strips (T)

Attribute	Description
Technical Attributes	
Target	Drivers who unintentionally cross into the left shoulder from the travel lane. For the application here, the target population is drivers leaving the left or median side of a divided freeway or expressway.
Expected Effectiveness	On freeways, right shoulder rumble strips have proven to be a very effective way to warn drivers that they are leaving or are about to leave the road. According to FHWA, several studies have estimated that right shoulder rumble strips can reduce the rate of ROR crashes by 20 to 50 percent, but it is not known how well this number can be

EXHIBIT V-2 (Continued)

Strategy Attributes for Left Shoulder Rumble Strips (T)

Attribute	Description
	<p>translated to a reduction in cross-median head-on crashes; it potentially would be lower and would also depend on the median width. <i>NCHRP Report 500, Volume 6: A Guide for Addressing Run-Off-Road Collisions</i> gives a detailed description and the statistics regarding effectiveness for specific programs applied to two-lane rural highways.</p> <p>In a recent study, the FHWA used data extracted from the Highway Safety Information System (HSIS) to study continuous rolled-in right shoulder rumble strips installed on 284 miles of rural and urban freeway in Illinois and 122 miles in California. Where possible, the author used two different before/after methodologies, one involving “yoked” or paired comparison sites and one involving a non-paired comparison group. In contrast with the more restricted group of accident types in the New York Thruway study (FHWA, 1999), all single-vehicle ROR crashes were studied. The Illinois data indicated an 18.3-percent reduction in single-vehicle ROR crashes on all freeways combined and a 13-percent reduction in single-vehicle ROR injury crashes. Both reductions were statistically significant. Comparable reductions on Illinois rural freeways were 21.1 percent for single-vehicle ROR crashes and 7.3 percent for injury crashes. California data for the combined urban and rural freeways indicated a 7.3-percent reduction in single-vehicle ROR crashes, but the finding was not statistically significant.</p> <p>Additionally, from studies of right shoulder rumble strips there have been no significant adverse findings from their use that would be potentially related to applications in the median (inside) shoulder except those related to maintenance of rolled-in rumble strips, and drainage issues discussed below.</p> <p>In summary, the effectiveness of left (median) rumble strips has not been specifically evaluated as a measure to reduce cross-median head-on crashes. Studies of right shoulder rumble strips have been shown to reduce the frequency of ROR crashes which could be potentially considered as a surrogate measure to assess their potential effectiveness related to cross-median head-on crashes. It would seem that if fewer ROR maneuvers occur or fewer motorists leave the travel lane then the cross-median crash potential is reduced.</p>
Keys to Success	<p>To be effective, left (median) shoulder rumble strips should be installed over a continuous length of facility. See discussion below—the design should enable drainage, not create maintenance problems, and should be incorporated with other reconstruction or resurfacing of the roadway and shoulder.</p>
Potential Difficulties	<p>Some potential pitfalls include complications with snow removal, shoulder maintenance requirements, and noise. With respect to adverse weather, ice and snow can collect in rumble strips. When the trapped water freezes, icy conditions may occur. However, if properly designed to accommodate for drainage requirements for shoulders, as well as speed, turbulence, and vibrations from passing vehicles, such factors tend to knock the ice from the rumble strips.</p> <p>There have been reports of noise complaints where shoulder rumble strips have been installed. New installations should acknowledge this concern and make provisions where necessary. Implementing a program of left rumble strips system-wide should consider local sensitivities to maintain support for such a program.</p>
Appropriate Measures and Data	<p>In implementation evaluations, <i>process measures</i> would include the number of road miles or number of hazardous locations where left rumble strips are installed. Process measures may include the aspect of exposure, and the number of vehicle-miles of travel exposed to left shoulder rumble strips.</p>

EXHIBIT V-2 (Continued)

Strategy Attributes for Left Shoulder Rumble Strips (T)

Attribute	Description
Associated Needs	<p>Impact measures will include the number (or rate) of head-on crashes reduced at these locations along with any change in total crashes. If possible, the impact measure should consider potential “crash migration” (i.e., crashes occurring on downstream sections where left shoulder rumble strips have not been applied, but where fatigued or inattentive drivers may be still driving).</p> <p>The strategy will be most effective when data and an analysis methodology exist to target the implementation of the most appropriate sites—a methodology that identifies sites based on head-on rather than total crashes. Accident data, traffic volume data and roadway data will be required to identify appropriate sites for the installation.</p> <p>There have been a few reports of people who mistook the sounds produced by the rumble strips as car trouble. A public information or education campaign, as well as standard installation, should eliminate such misinterpretations. However, current moves to their standardized use on freeways may provide the most effective public training.</p>
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	<p>Many states have established specific design and placement policies for the placement of right shoulder rumble strips. From the experience of these agencies it does not appear that significant extra coordination with other agencies is needed for the installation of left shoulder rumble strips.</p> <p>Reviews of freeway-related policies from Connecticut, New Hampshire, New Jersey, Massachusetts, Maine, and Minnesota indicate that factors considered in their installation include minimum shoulder width criteria, offset from edge line, and placement on or near bridge decks. Since 1991, the Kansas DOT has had a policy requiring right shoulder rumble strips to be included on all reconstruction or new construction projects with a full width (8- to 10-foot) shoulder. Right shoulder rumble strips were also required if full-width shoulders were being overlaid with a minimum of 1 inch of asphalt. This policy primarily pertains to freeways and expressways. Other states such as Connecticut, New Hampshire, New Jersey, Maine, and Minnesota consider similar factors. Finally, experience has indicated that rolled-in rumble strips applied on asphalt pavements have shown a tendency to deform over time, thus reducing the size of the cuts and lessening their effectiveness to alert drivers. This is leading states to utilize milled rumble strips as discussed earlier.</p> <p>The development of a framework and methodology for the application of left shoulder rumble strips that considers items outlined above assists in their appropriate installation as they would likely be within an agency’s current design standards and policies.</p>
Issues Affecting Implementation Time	<p>This low cost strategy does not involve reconstruction and would not involve an environmental process or right-of-way acquisition. Left shoulder rumble strips in many instances can be implemented quickly, certainly within 1 year once a site is selected if the existing shoulder is in good condition and the shoulder width is adequate.</p>
Costs Involved	<p>Costs will vary depending on whether the strategy is implemented as a stand-alone project or incorporated as part of a reconstruction or resurfacing project already programmed.</p> <p>Due to increased installation and technological advances, the cost of continuous right shoulder rumble strips has decreased over the years. For instance, in 1990, the New York DOT reported paying \$6.18 per linear meter compared with \$0.49 per linear meter in 1998. Specific costs of installation on the New York Thruway were reported to be \$3,995 per roadway mile for rumble strips on all four shoulders. The cost included</p>

EXHIBIT V-2 (Continued)

Strategy Attributes for Left Shoulder Rumble Strips (T)

Attribute	Description
	milling in the rumble strips, sweeping and discarding excess asphalt, and maintaining and protecting traffic.
Training and Other Personnel Needs	There appear to be no special personnel needs for implementing this strategy. States can either use agency personnel or contractors. The need for training will depend on whether the agency has been using retrofitted rumble strips on freeways or other roadways. If not, either agency or contractor personnel will need to be trained in proper installation techniques.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	None identified.
Other Key Attributes to a Particular Strategy	None identified.

Strategy 18.2 A2—Provide Enhanced Pavement Markings and Median Delineation (T)

General Description

The main focus of this strategy is to provide better pavement marking guidance and delineation where there is a possibility for a driver leaving the roadway. Pavement markings serve a primary function to provide guidance and information in the form of visual cues for the road user particularly under adverse visibility conditions and at night. In some cases markings may be the primary means to effectively convey guidance and warning in ways not obtainable by other devices. The goal of this strategy is to mark the roadway more clearly so that drivers will use the information to stay in their lanes and not merely to increase their speed. The specific markings used for this strategy are typically low-cost, readily available materials.

The strategies discussed below are divided into three groups: enhanced (or better) pavement markings, raised pavement markings, and post mounted delineators. As discussed in *NCHRP Report 500, Volume 7: A Guide for Reducing Collisions on Horizontal Curves* (<http://safety.transportation.org/>), enhanced markings are those that may be more durable, wider, all-weather, or have a higher retroreflectivity than traditional pavement markings.

Enhanced pavement markings are highly reflective in both wet and dry conditions (see Exhibit V-3). If they consist of tape and are applied in snow removal areas, the tape can be installed in grooved (inlaid) pavement to avoid plow damage. A more visible and durable form of traffic paint is also available in the form of what is termed “All Weather Paint.” This material consists of a diverse composition of microcrystalline ceramic beads which provide enhanced visibility in both wet and dry conditions and utilizes a resin compound to permit a thicker application and increased bonding ability for beads. Paint placed over rumble strips helps to make them visible; these are called rumble stripes (FHWA).

EXHIBIT V-3

Example of Wet Reflective Enhanced Pavement Markings

Source: 3M Corporation



Raised pavement markers provide delineation over a wider range of environmental conditions than can be achieved with standard pavement marking materials. There are a variety of types and models in the form of snow plowable and non-snow plowable markers. Post mounted delineators are treatments installed outside the roadway and can be mounted using sign posts or flexible tubing. Typically they are used in situations to warn drivers of an approaching curve and provide tracking and guidance. While their intent is to provide a warning, it should be remembered that posts placed along the roadside can represent a possible object with which an errant vehicle may crash. Accordingly, they should be designed to minimize the potential for damage and injury when selected.

EXHIBIT V-4

Strategy Attributes for Enhanced Pavement Markings and Delineators (T)

Attribute	Description
Technical Attributes	
Target	Drivers who may leave the roadway because of the inability to see the edge of the pavement or changes in roadway alignment.
Expected Effectiveness	This strategy is considered “Tried” but unproven related to specific effectiveness for freeway and expressway median treatments. Studied applications of this strategy for the most part involve two-lane highways, or involve inadequate study design (e.g., ‘regression to the mean’ effects).
	Enhanced lane markings (T). Enhanced lane markings as described in <i>NCHRP Report 500, Volume 6: A Guide for Addressing Run-Off-Road Collisions</i> as an appropriate treatment for drivers who leave the roadway because they cannot see the pavement edge in the downstream roadway sections. While some driver guidance is needed in such cases, the question is: How much should be added without changing the roadway geometry or the roadside design? Additional details relating to application of

EXHIBIT V-4 (Continued)

Strategy Attributes for Enhanced Pavement Markings and Delineators (T)

Attribute	Description
	<p>enhanced markings are contained in <i>NCHRP 500, Volume 6: A Guide for Addressing Run-Off-Road Collisions</i> (http://safety.transportation.org/).</p> <p>For example, past research (Pendleton, 1996) indicates a lack of significant effectiveness or even a possible increase in crashes at some locations. This could be because drivers tend to drive faster when presented with a clearer delineation of the lane edge. However, evaluations of such treatments reflect studies of projects involving delineation that was implemented in conjunction with resurfacing. What is not clear is whether speeds increased because of simultaneous resurfacing and remarking or because improved markings were added without alignment or shoulder treatments.</p> <p>Various methods are available to enhance the delineation along a curve. Some of the traditional devices include chevron signs or post-mounted delineators (discussed below) which are placed along the outside of the road. Other devices that are placed on the surface of the travel way include wide edge lines (8 in. or 200 mm), and raised pavement markers (discussed below). The safety effectiveness of enhanced delineation devices for horizontal curves is difficult to assess due to conflicting research and this is in part due to the need to use surrogate measures such as lateral vehicle placement in the lane and speed behavior rather than the ability to use crash data. <i>NCHRP 500, Volume 7</i> gives a detailed description of the safety effectiveness of these measures. No studies were found which have assessed the safety effectiveness of these devices as related to head-on crashes.</p> <p>Raised pavement markings (RPMs) (T). Effectiveness studies of RPMs have been conducted by states in before/after analyses of treatments at high-hazard locations. (It should be noted that accurately evaluating a treatment at a high-crash location is difficult because of the “regression to the mean” phenomenon.) <i>NCHRP Report 518, “Safety Evaluation of Permanent Raised Pavement Markers,”</i> conducted a comprehensive study of the efforts by DOTs. The effect of using RPMs on four-lane freeways was reviewed and a study by Wisconsin DOT was cited. The study, when analyzed by the NCHRP study team, showed conflicting results in quantifying the safety benefits. A study from Missouri showed significant reductions in fatal and injury crashes (5.4 percent), daytime fatal and injury crashes (6.2 percent), and guidance-related crashes (10.3 percent). A study from Pennsylvania showed significant reductions in total crashes (5.7 percent) and daytime crashes (6.5 percent) after the installation of RPMs. None of the studies specifically looked at head-on crashes.</p> <p>In Ohio, marker studies were conducted at 184 locations that had high accident rates prior to 1977, including horizontal curves, narrow bridges, stop approaches, and interchanges. Over 3,200 accidents at marker locations were analyzed 1 year before and 1 year after (see above comments about regression to the mean). The results show a 9.2 percent reduction in accidents and a 14.9 percent decrease in injuries. Markers were determined to be effective in all types of driving conditions, including nighttime (5.3 percent reduction) and adverse weather conditions (5.5 percent reduction in crashes at the same time precipitation increased by 10.6 percent). The study concluded that “a dollar spent on raised reflective highway markers in Ohio has returned \$6.50 in savings due to accident reduction.” As of 1981, nearly 700,000 RPMs were installed in Ohio (<i>The Ohio Underwriter</i>, 1981).</p> <p>Post Mounted Delineators (T). There have been few studies to investigate the safety impacts of post mounted delineators separate from other treatments. Most of the</p>

EXHIBIT V-4 (Continued)

Strategy Attributes for Enhanced Pavement Markings and Delineators (T)

Attribute	Description
Keys to Success	<p>studies have reviewed sites where they were used in combination with other treatments such as pavement markers, raised pavement markers, and chevrons. For freeways or expressways, no studies have been identified. For situations of two-lane roads there is discussion of studies conducted on the effect of post mounted delineators in <i>NCHRP Report 500, Volume 7: A Guide for Reducing Collisions on Horizontal Curves</i>. The report focuses on the impact related to relatively sharp curves.</p>
Potential Difficulties	<p>Based upon the effectiveness studies, the key to success is the targeted application of this treatment to sites where more guidance is needed for the driver, but where vehicle speeds will not be increased to potentially unsafe levels.</p> <p>A potential difficulty with RPMs would be damage to the reflector during snow plowing. The use of snow plowable RPMs where snow occurs has reduced this concern. Several states have encountered a few difficulties with RPMs placed in asphalt due to winter conditions. According to reports from these states, as the asphalt deteriorates, asphalt is apparently weakened by freeze-thaw cycles. If the pavement is not inspected and maintained, the reflectors may eventually come loose. No similar issues have been observed with RPMs placed in concrete pavement. The visibility of pavement markings can be compromised if not properly maintained and their durability is affected by weather, material properties, traffic volumes and location and may subsequently degrade.</p>
Appropriate Measures and Data	<p>In agency evaluations of implementation effectiveness, process measures would include the number of hazardous curves or roadway sections treated and the type of treatment applied.</p> <p>Impact measures would involve before/after changes in crash frequencies or rates (when the study is appropriately designed) and changes in speed from before to after treatment.</p> <p>It would also appear that data are needed to better target these treatments, targeting to sites where additional visual guidance is needed, but where speeds are less likely to be increased. This is a difficult task. It may be aided by use of video logs and conduct of safety audit types of studies.</p>
Associated Needs	None identified.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	<p>These treatments could be implemented by a state DOT, or a local roads agency. It does not appear that additional cooperative efforts with other agencies are necessary. One exception might be for treatments related to enhanced delineation such as RPMs for which there is some evidence of a potential for increased speeds. In this case speed monitoring after installation and targeted enforcement may be needed.</p> <p>After the effectiveness and durability of a treatment are established and targeting techniques are developed, a design and installation policy is needed to facilitate implementation, consistent with AASHTO guidance and support.</p>
Issues Affecting Implementation Time	Since these treatments represent a relatively inexpensive strategy, they can be implemented in a short time frame.
Costs Involved	Low cost strategy.

EXHIBIT V-4 (Continued)

Strategy Attributes for Enhanced Pavement Markings and Delineators (T)

Attribute	Description
Training and Other Personnel Needs	There appear to be no special personnel needs for implementing these treatments. States could either use agency personnel or contractors. The need for training will depend on whether the agency has previous experience with these devices on freeways or other roadways. For example, training may be necessary if a new type of device was installed such as a more crashworthy, or more flexible, delineator. If not, either agency or contractor personnel will need to be trained in proper installation techniques.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	None identified.
Other Key Attributes to a Particular Strategy	None identified.

Strategy 18.2 A3—Provide Improved Pavement Surfaces (T)

FARS statistics from 2001 show that 13 percent of cross-median crashes on Interstates occur on wet surfaces and 4 percent occur on roadways with snow and ice. Accidents on wet pavement are often related to the pavement's skid resistance. The level of pavement skid resistance required generally depends on the volume of the traffic and speed. Additionally, geometric conditions may play a role.

Skid resistance is the force developed when a tire that is prevented from rotating slides along the pavement surface. A vehicle may skid during braking and maneuvering if frictional demand exceeds the available friction at the tire-pavement interface. While this can occur on dry pavement at high speeds, the friction force is significantly reduced by a wet or icy pavement surface. For example, a water film thickness of 0.002 inches reduces the tire to pavement friction by 20 to 30 percent of the dry surface friction. Water can also build up on pavement surfaces due to tire rutting. An inadequate crown and poor shoulder maintenance can also increase the potential for vehicle hydroplaning in wet conditions. An important parameter to minimize the potential that water will accumulate or build up is the provision of adequate pavement drainage design. In addition, improvements or countermeasures are available to increase the skid resistance (higher friction factor) of a pavement surface. Countermeasures to improve the skid resistance include asphalt mixture (modification of type and gradation of aggregate as well as asphalt content), pavement overlays on both concrete and asphalt pavements, and pavement grooving or grinding.

A 48-state survey was conducted by Texas Tech University to evaluate pavement skid resistance (TranSafety, 1997). Research has shown that pavement macrotexture greatly influences skid resistance. As driving speeds and average daily traffic increase, the chances of having a skid-related accident which can develop into a cross-median crash also increase and the chances are compounded if the pavement is wet.

EXHIBIT V-5
Strategy Attributes to Provide Improved Pavement Surfaces (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	Treatment will target locations where skidding or poor pavement surface is determined to be a problem, in wet or dry conditions. With respect to head-on crashes the target vehicle is one that runs (skids) off the road due to insufficient skid resistance and becomes involved in a head-on crash after an over-correction.
Expected Effectiveness	New York State has implemented a program that identifies sites statewide that have a low skid resistance and treats them with overlays or microsurfacing as part of the maintenance program. Between 1995 and 1997, 36 sites were treated on Long Island, resulting in a reduction of more than 800 annually recurring wet-road accidents. These results support earlier findings that improving the skid resistance or pavement surface at locations with high wet-road accident frequencies results in reductions of 50 percent for wet-road accidents and 20 percent for total accidents. While these results could be subject to some regression-to-the-mean bias, there is an indication that improving the skid resistance of pavement surfaces reduces wet-road and total accidents. Some states, including California, resurface short roadway segments such as horizontal curves with open-graded asphalt friction courses to improve skid resistance and safety.
Keys to Success	Monitoring the skid resistance of pavement requires incremental checks of pavement conditions. Evaluation must identify ruts and the occurrence of polishing. Recent research (Galal et al., 1999) has suggested that the surface should be restored between 5 and 10 years in order to retain surface friction, but the life span is affected by site characteristics such as traffic volume.
Potential Difficulties	A 1980 Technical Advisory by the FHWA provides a detailed description of a “Skid Accident Reduction Program,” including not only the details of various treatments, but also the use of crash and rainfall data in targeting the treatments (see http://www.fhwa.dot.gov/legsregs/directives/techadv/t504017.htm). Skid resistance changes over time. This requires a dynamic program and strong commitment. As noted in the preceding section, it also requires good “targeting” and the monitoring of pavement conditions. When selecting sites for skid resistance programs, it is important to somehow control for the amount of wet-pavement exposure. Unfortunately, it is difficult or impossible for an agency to develop good wet-pavement crash rates per vehicle mile for all roadway sections due to the lack of good wet-weather exposure data for all sites.
Appropriate Measures and Data	Data are needed on traffic crashes by roadway condition. In addition, measures of traffic exposure that identify and reflect both dry and wet periods are needed. Finally, measurements of road friction and pavement water retention should be documented both before and after implementation of a strategy.
Associated Needs	There doesn’t appear to be a need for any public information and education as these types of treatments are relatively unnoticed by the public.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	Policies are typically implemented by state DOTs and no coordination is required. A policy may need to be implemented to specify appropriate pavement improvements, including such items as pavement design and location selection criteria. Guidelines may be needed to specify when pavement grinding or groove cuts should be considered. These countermeasures may require cooperation within the agency,

EXHIBIT V-5 (Continued)

Strategy Attributes to Provide Improved Pavement Surfaces (T)

Attribute	Description
	especially if these types of safety measures are tied to routine maintenance, pavement design, or drainage design.
Issues Affecting Implementation Time	Depends upon the treatment. Grooving and grinding can be done quickly, but overlays or drainage modifications require more time. Nevertheless, all strategies being suggested should have short implementation periods.
Costs Involved	Highly variable depending upon the specific treatment and extent. The New York State DOT estimates that its resurfacing/microsurfacing projects are approximately 0.5 miles long, with an average treatment cost of approximately \$20,000 per lane mile (1995 dollars). In recent years potential costs are likely to be higher.
Training and Other Personnel Needs	No special personnel needs for implementing this strategy. Either agency personnel or contractors could implement.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	None Identified.
Other Key Attributes to a Particular Strategy	None identified.

Objective 18.2 B—Minimize the Likelihood of Head-on Crashes with an Oncoming Vehicle

This objective considers the situation in which the vehicle has already left the lane and is in the median. The strategies involve preventing the vehicle from crossing over into the other direction of travel and being involved in a cross-median head-on crash, and helping to redirect the vehicle in the direction of flow. The objective is not prevention of a crash, but minimizing the potential of a severe head-on crash.

Central to the objective is utilization of the median. There are several principal purposes and advantages in providing a median. Medians separate opposing traffic streams, provide a recovery area for out-of-control vehicles, and provide a place for vehicles to stop in the event of an emergency. In addition, some medians and median barriers can potentially reduce oncoming headlight glare from vehicles.

Strategy 18.2 B1—Provide Wider Medians (P)

This strategy involves providing greater median width where right-of-way is available. Wider medians can provide for the driver a greater sense of separation from opposing traffic, provide an increased recovery area for errant vehicles, potentially reduce headlight glare and provide width for future lanes. Median width is generally defined as the width of the portion of the divided highway separating the traveled ways for opposite directions

which includes the inside shoulders. Often right-of-way restrictions dictate the availability of median width. Medians may be raised, flush or depressed.

South Carolina reviewed fatality data for their state to investigate the cause of median-crossover crashes (Knuiman et al., 1993). Their investigation found that these incidents were random in nature and they did not appear to be related to specific locations. However, in one instance, a series of three crossover crashes that killed 13 people in a 3-month period on a 10-mile stretch of a freeway raised questions about this theory. The study of these three incidents did indicate that the probability of head-on crashes increases with a decrease in median width and increase in traffic volumes.

AASHTO, in a *Policy on Geometric Design of Highways and Streets* (Green Book), provides guidance for median widths under a range of conditions. Recommended widths can vary significantly, from as little as 10 ft to as much as 100 ft. Recommended median dimensions are not based on explicit studies of relative crash risk associated with median width.

For rural freeways the AASHTO Green Book indicates 50–100 ft as a common road median width. In flat terrain a 100 ft median width may be suitable if the addition of future travel lanes is contemplated. In areas where the right-of-way restrictions occur, or in mountainous terrain, a median width of 10–30 ft may be used. In rolling terrain a wide variable median with an average width of 150 ft or more may be used. This assists in blending the freeway into the natural topography and also permits potentially using the individual roadway alignment.

Hauer (2000) reviewed various studies relating to median safety and reached several conclusions. He found that as the median width increases, cross-median crashes decrease, particularly for medians wider than 50 ft. As the median width increases, median-related crashes may increase, reaching a peak at around 30 ft and then decreasing for medians wider than 30 ft.

The Wisconsin *Facilities Development Manual* (FDM) specifies that a minimum median width of 60 ft be used on all freeways and expressways with a speed limit greater than 55 mph, while a minimum median width of 50 ft should be used on expressways with a speed limit of either 50 or 55 mph. Even so, a study carried out for Wisconsin DOT in 2005 revealed that 81.5 percent of identified median-crossover crashes occurred at median widths and ADT combinations which did not warrant barrier under the Wisconsin standards, with over 55 percent of the total occurring with medians in the 60 to 69 ft range. The study, which evaluated 631 median crashes over the 3-year period between 2001 and 2003, revealed a suggested relationship between crashes and median width. These crashes resulted in over 600 injuries and 53 fatalities. Although the research indicated that there was some decrease in median-crossover crash rate with an increase in median width, it was not statistically significant.

The study noted that “though there was no strong direct relationship between median width and median-crossover crash frequency, there are other confounding variables that have an effect on whether a median-crossover crash occurs. Several of these variables, such as crash vehicle type, initial causation of crash, and age of driver have been documented in this research. Nevertheless, there are numerous ways that all these variables can interact to affect the crash. In addition, some variables, such as median cross slope, were unable to be examined for this research. The findings of this research in relation to median-crossover crash frequency and median width are significant, but more study needs to be done to further substantiate the effects that other confounding variables have on median-crossover crashes” (Noyce and McKendry, 2005, p. 95).

EXHIBIT V-6
Strategy Attributes for Use of a Wider Median (P)

Attribute	Description
Technical Attributes	
Target	Provide more recovery area for the errant vehicle in the form of a wider median for the vehicle which crossed the lane unintentionally.
Expected Effectiveness	<p>The HSIS report on the <i>Association of Median Width and Highway Accident Rate</i> indicates that accident rates decrease with increasing median width for unprotected medians (Knuiman et al., 1993). For a median width up to 30 ft there was a very little change in accident rate, which implies that the minimum median width should be made at least 30 ft for the new highways. According to this study safety benefits increased until the median width of 60–80 ft was reached—Illinois and Utah state databases were used for the analysis. The report also states that the rate of multi-vehicle accidents declines steadily with increasing median width but for single-vehicle accidents it showed little relationship, at least in the case of Utah.</p> <p>Hauer (2000) reviewed various studies relating to median safety and reached several conclusions. He found that as the median width increases, cross-median crashes decrease, particularly for medians wider than 50 ft. As the median width increases, median-related crashes may increase reaching a peak at around 30 ft and then decrease for medians wider than 30 ft. There was no conclusion drawn about the effect of increasing median width on total crashes. Garner and Deen (1973) compared various median types on divided, four-lane Interstate highways with similar geometric features in the state of Kentucky. Their data indicated that accident rate decreases with an increase in the median width up to approximately 30 to 40 ft, where accident rates then level off. According to the study, deeply depressed medians were discouraged due to a higher rollover potential. Raised medians are also to be discouraged as they showed an increase in crashes in which a vehicle struck the median and then consequently lost control.</p>
Keys to Success	The keys to success will be sound evaluations that can define safety-related effectiveness. In such evaluations ADT information, median type, terrain, curvature, and width need to be accounted for.
Potential Difficulties	<p>This strategy is not applicable as a short-term, low-cost strategy. It would apply more to projects in the planning phase, and also to DOTs looking at their design policies with a perspective on safety.</p> <p>Acquisition of right-of-way on urban freeways is very expensive and the overall cost of reconstructing an existing facility to provide a wider median can be expensive including implementation logistics.</p>
Appropriate Measures and Data	The strategy will be most effective when data and an analysis methodology exist to target the implementation of the most appropriate sites. The methodology should identify sites based on cross-median head-on crashes rather than total crashes.
Associated Needs	None
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	<p>This strategy would be implemented by state and local roadway agencies, and it doesn't appear that extra coordination with other agencies or groups is needed.</p> <p>If a state DOT does not have a policy defining median width which should include traffic characteristics, one may be needed. Most states use median width criteria for median barriers similar to those published in AASHTO's <i>Roadside Design Guide</i>.</p>

EXHIBIT V-6 (Continued)

Strategy Attributes for Use of a Wider Median (P)

Attribute	Description
Issues Affecting Implementation Time	Reconstruction of freeways is a multi-year process. The timing depends on the need to acquire new right-of-way, environmental issues, and the complexity of design related to the modification.
Costs Involved	Cost of construction and maintenance typically increases as the median width increases. The cost would make this strategy applicable generally only in rural areas.
Training and Other Personnel Needs	None identified.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	None identified.
Other Key Attributes to a Particular Strategy	None identified.

Strategy 18.2 B2—Improve Median Design for Vehicle Recovery (T)**Pavement Edge Drop-offs**

Differences in elevations between a travel lane and the shoulder or roadside can be potentially hazardous (see Exhibit V-7). An increase in the elevation difference can generally occur when the pavement is resurfaced or the pavement to the adjacent ground has deteriorated. According to the FHWA, an edge drop-off of 4 or more inches is considered unsafe if the

EXHIBIT V-7

Example of Problematic Pavement Edge Drop-off

Source: FHWA



roadway edge is at a 90° angle to the shoulder surface. Near-vertical edge drop-offs of less than 4 inches are still considered a safety hazard to the driving public and may cause difficulty upon reentry to the paved surface.

Research has shown that the ability of a driver to recover from a pavement-edge drop-off is a function of edge-drop height and shape, vehicle speed, path angle, and available recovery area. The probability of the safe recovery of the errant vehicle increases if there is a smooth area for the recovery and there are no irregularities in the pavement edges but decreases as the vertical differential increases. The best practice would always be to retain the travel way and the shoulder at the same level. AASHTO recommends that pavement-edge drop-offs not exceed 2 inches.

There are various measures that are in use for treating an edge drop-off that is significant. The measure to treat the drop-off depends on the following factors: shape and depth of the difference in lane pavement and shoulder surface elevation, traffic volume, speed limit, longitudinal lengths, and duration of the drop-off.

Measures to advise motorists of their presence or to improve drop-offs include: placing a wedge or fillet at 30 to 35 degrees or flatter slope along the face of the drop-off (see Exhibit V-8), adding pavement markings to delineate the edge of pavement or travelway, and placing channelizing devices along the traffic side of the drop-off. When considering any of the above treatments the speed limit and traffic volume of the roadway need to be considered.

The Georgia DOT working with the FHWA has demonstrated the ability to construct the “Safety Edge” (see Exhibit V-9) with no impact on production and at less than 1 percent additional material costs. Based on successful performance after 1 year in service, Georgia DOT intends to incorporate the “Safety Edge” design into all resurfacing projects. Local city and county governments in Georgia, such as Gwinnet County, are also making the safety edge part of their routine overlay design. Other state DOTs, such as Indiana DOT and the New York DOT, have implemented the safety edge on several pilot projects in 2005 (see http://safety.fhwa.dot.gov/roadway_dept/index.htm).

EXHIBIT V-8

An Inexpensive Way to Ensure Pavement Edge Safety is to Specify a 30°–35° Angle Asphalt Fillet

Source: FHWA

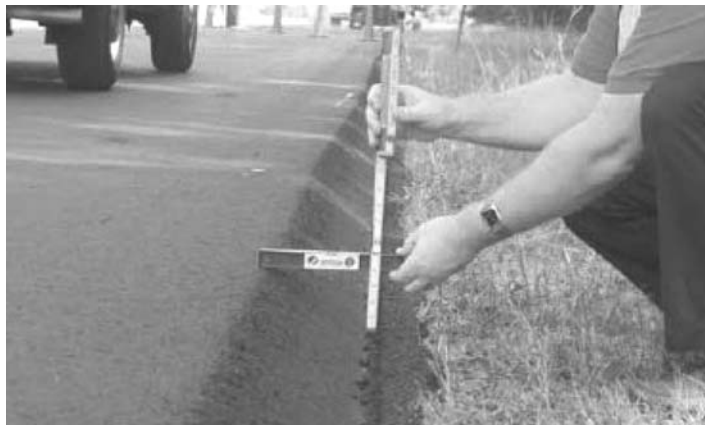


EXHIBIT V-9

Example of Georgia DOT “Safety Edge” Installation and Final Improvement

Source: FHWA



Improve Median Slope Design Related to Head-on Crashes

There appear to be trade-offs when considering the design of a median and its effect on mitigating various crashes. Assuming a vehicle has left the traveled way, the objective of a median design should be two-fold: one, to provide a safe recovery area for the errant vehicle without rolling over, and two, to not have the errant vehicle cross the median and crash head-on with oncoming cars. With respect to rollover crashes it is known that these crashes can be reduced by improving the side slopes and ditches. For example, the *AASHTO Roadside Design Guide* (2002) categorizes foreslopes parallel to the roadway as follows:

- **Recoverable slopes** are 1V:4H or flatter. A motorist who leaves the roadway onto a recoverable slope can normally stop or slow down and return to the roadway safely.
- **Non-recoverable slopes** are between 1V:3H and 1V:4H. These slopes are traversable but most vehicles will be unable to stop or return to the roadway easily. Vehicles will normally travel to the bottom of non-recoverable slopes.
- **Critical slopes** are steeper than 1V:3H. Vehicles are likely to overturn if they leave the roadway onto a critical slope.

The *AASHTO Roadside Design Guide* categorizes slopes that are 1V:6H or flatter as desirable from a safety perspective. Exhibit V-10 illustrates a median with relatively flat slopes. This is because flatter slopes and ditches will reduce the likelihood of single-vehicle rollover crashes and increase the probability that an errant motorist can safely regain control. However, in the context of considering the potential related to an increase in cross-median crashes—particularly for narrow medians, care should be exercised when flattening median slopes as it may increase the probability of a vehicle crossing the median and potentially cause a severe head-on crash with one or more vehicles in the opposing travel lanes.

This has been a concern by some DOTs but there is limited, anecdotal information available on the extent to which median slopes contribute to or help prevent cross-median crashes. Information is also limited in terms of what the optimal slopes are for medians of various widths. Until the issue is better understood, it's important to take the potential effect on cross-median crashes into account when designing median foreslopes or flattening existing slopes.

EXHIBIT V-10

Median with Relatively Flat Slopes



Flattening the slopes of narrow medians should be approached with care. Although it will increase the likelihood of safe recovery, flattened slopes may allow an errant vehicle to more easily cross the median into opposing traffic.

In designing a median to mitigate the potential for crashes it is also important to consider appropriate soil types to minimize the possibility for rollover. Slopes should also be designed to provide adequate channels to convey storm runoff.

In summary it is important to consider the types of crashes that occur when vehicles leave the traveled way and enter a median and that attempting to minimize the potential of one crash pattern may have an unintended consequence of increasing another.

Paving Shoulders

The paving of a shoulder is a technique that helps to promote a safe recovery for an errant vehicle and may help to deter the potential for cross-median crashes. The paving of a shoulder can be done in conjunction with a variety of shoulder treatments including but not limited to the addition of a left (median) shoulder rumble strip or elimination of a pavement edge drop-off. With respect to head-on median crashes the treatment assists in permitting a vehicle recovery in a more controlled fashion, thereby reducing the chances that the recovering vehicle will over-correct and lose control.

Other benefits of providing a shoulder include the ability to accommodate a stopped vehicle so that it does not encroach onto a travel lane, the facilitation of access for emergency vehicles, protection of the integrity of the pavement, facilitation of roadway maintenance and as indicated above the provision of an opportunity to install a median shoulder rumble strip. A potential negative of a paved shoulder is that the intent to provide for vehicles that have to stop can result in the stopped vehicle becoming a hazard. It has been estimated that more than 10 percent of all fatal freeway accidents may be associated with stopped-on-shoulder vehicles or the maneuvers associated with leaving and returning to the travel lane.

Strategy 18.2 B3—Install Median Barriers for Narrow-Width Medians (P)

This strategy involves providing a barrier to separate opposing traffic on a divided highway. When an errant vehicle leaves the road and enters the narrow median there is a higher probability that the vehicle may cross the median and hit the opposite oncoming vehicle as the width of the median decreases.

As traffic volumes increase, particularly in urban areas or on rural freeways or expressways that connect urban areas, there is a potential that the median width will be decreased to provide added travel lanes. The cost of acquisition of new right-of-way may also limit the median width. When this occurs there is a need to consider the installation of median barriers in a median.

Most states follow median barrier warrants set forth in AASHTO's *Roadside Design Guide*. AASHTO's current guidance for median barrier installation is based on a function of average daily traffic and width of the median. For all median widths between 30 ft and 50 ft, and also in cases where the median width is less than 30 ft and the ADT is less than 20,000, a median barrier is considered to be optional. According to long-standing AASHTO guidelines, barriers are not normally considered for median widths greater than 50 ft.

Recent experience suggests that the AASHTO warrants may require adjustment for certain conditions. A nationwide survey of cross-median crashes in several states, conducted by the FHWA in 2004 and based on responses from over 25 states, found that there were a significant percentage of fatal cross-median crashes occurring where median widths exceeded 30 ft. Indeed, the survey found that some cross-median crashes occurred in medians in excess of 200 ft wide, with approximately two-thirds of the crashes occurring where the median was less than 50 ft in width.

In recent years, several states noticed an increase in the number of cross-median crashes and developed new guidelines for their highways that expanded the use of median barriers. North Carolina, California and Georgia are three states that have active median safety programs. Another example is New Hampshire, which considers the installation of median barriers on medians with widths less than 50 ft.

New York also requires that median barrier protection should be considered for all traversable median locations up to 72 ft in width, and for wider medians where cross-median crashes have occurred. Priority is given to areas with high speeds (55 mph and greater), high truck volumes (10 percent or greater), heavily congested corridors, and/or areas where one or more cross-median crashes have occurred during the previous 5 years.

North Carolina uses a three-pronged proactive strategy to prevent cross-median crashes:

- Identify and install protective median barriers on freeways with cross-median crash histories.
- Protect with barrier all freeway sections with median widths of 70 ft or less.
- Revise policies to prevent the construction of additional freeway sections with unprotected narrow medians.

The California Department of Transportation (Caltrans) evaluations consider the traffic volume/median width warrant as well as an accident study warrant. In 1997 they completed a detailed study that suggested medians as wide as 75 ft with traffic volumes in excess of

60,000 vehicles per day would be candidates for a median barrier study. Caltrans also uses an accident study warrant to identify sections of freeway that may require median barriers. This warrant requires a minimum of 0.50 cross-median accidents of any severity per mile per year or 0.12 fatal cross-median accidents per mile per year. The rate calculation requires a minimum of three accidents occurring within a 5-year period. A benefit/cost (B/C) methodology was developed for the state of Washington to evaluate traffic barrier solutions for across-the-median crashes. The study showed that a barrier placed in median sections up to 50 ft wide is cost effective. The B/C ratios indicated that cable barrier is the most cost-effective system, based on the assumptions of the study. Recommendations from the study included the installation of median barrier on all medians on full access control, multi-lane highways with posted speeds of 45 mph or greater where medians are 50 ft wide or less, with the type of barrier to be determined on a project-by-project basis. Cable barrier may be particularly suited for use as a retrofit design in existing relatively wide and flat medians.

AASHTO's *Roadside Design Guide*, covering median barriers, is presently being reviewed and revised as necessary to reflect changes in the factors affecting the probability of cross-median accidents, including changes in the vehicle fleet and the percentage of heavy trucks using the roadway.

The proposed revisions to AASHTO's *Roadside Design Guide* will provide new guidelines for the use of median barriers, information on high tension cable barrier, and new guidance on placement of cable barrier in the median. Appendix 1 contains a memorandum prepared with the assistance of Dick Albin of Washington State DOT on the status of AASHTO's proposed revisions as of December 2005.

Note that median barriers may only be necessary at locations where there are concentrations of cross-median crashes. For these reasons, a one-size-fits-all recommendation for the use of median barriers is not appropriate.

Barrier Placement

States have placed median barrier at various locations (offsets) within the median and there are advantages and disadvantages associated with each. For all locations, flat approach slopes are desirable for optimal barrier performance. The slopes and ditch depths must provide adequate drainage which places practical limits on this objective (unless an enclosed drainage system is used, which greatly increases cost).

The main reason cited by proponents of placing the barrier near the center of the median or on the foreslope is that fewer impacts are expected (see Exhibit V-11). Some motorists that have left the roadway may be able to recover before striking the barrier. Incidental impacts from snow plows or other maintenance operations can be minimized. Appendix 2 shows a sample log of cable impacts from the Arkansas DOT.

Disadvantages of placing the barrier at this location are: (1) terrain irregularities on the median slopes and the ditch can affect vehicle stability from both directions (more information on this issue specific to cable barrier is provided below), and (2) barrier placed on the grassy portions of the median will require mowing and weed control.

Cable barriers have been shown to perform effectively when placed on 1V:6H slopes. However, experience in some states has shown that some vehicle types (most with low front profiles) can override the barrier when impact occurs after traversing the bottom of the

EXHIBIT V-11

Barrier Placed Down Center of Median

Source: Oklahoma DOT, Lake Hefner Parkway



ditch. Based on computer simulation and limited crash testing, current guidance is that placement of cable barriers should be avoided in the area from 0.3 m (1 ft) to 2.4 m (8 ft) from the ditchline on 1V:6H slopes. Some manufacturers of proprietary cable barrier systems also do not recommend placing the barrier at the bottom of a V-ditch with 1V:6H slopes.

Some states have placed barrier on the outside edge of one shoulder (see Exhibit V-12). One clear maintenance advantage to this approach is no need for mowing and a reduced need for weed control. Vehicles impacting from the near side will also be more likely to strike the barrier in a stable condition as they will be on the paved shoulder at the point of impact. One state placed cable barrier at this location due to different profiles for the two directions of the freeway. The barrier was placed on the “high-side” edge of shoulder.

Current guidance for strong post guardrail systems placed on paved shoulders or paved mow strips is that the post holes should be large enough to allow post deflection at the ground line. See the following website for additional information: http://safety.fhwa.dot.gov/roadway_dept/road_hardware/barriers/pdf/b64b.htm.

The disadvantage most often cited for placing barrier on the edge of shoulder is more frequent impacts from the near side and the potential for incidental impacts from snow plows or other maintenance operations.

Some states provide guidance as to which type of barrier should be used at a particular location. For example, Caltrans provides a table to indicate which of their two approved standard types of median barrier (concrete barrier or thrie beam) should be used, together with placement guidelines. Typically, Caltrans prefers the use of concrete barriers for median widths equal to or less than 36 ft, although thrie beam may be installed where otherwise justified and approved. Thrie beam is the preferred choice on wider medians in California.

EXHIBIT V-12

Barrier Placed on Pavement at Edge of Shoulder

Source: Oklahoma DOT, Lake Hefner Parkway



The proposed revisions to AASHTO's *Roadside Design Guide* include reference to several High-Tension Cable Barrier systems that have been developed and are increasing in use. Please refer to the *Roadside Design Guide* for additional details on the various barriers and to the appendixes of *NCHRP Report 500, Vol. 20* on the AASHTO website.

With regard to the relative effectiveness of different types of median barriers, Washington State Department of Transportation (WSDOT) analyzed 11,457 median barrier collisions that occurred on Washington State highways from 1999 to 2004, and found that occupants of vehicles striking cable barriers were less likely to be injured or killed than those striking concrete barrier or guardrail. This is partly because cable barrier is far less likely to redirect an errant vehicle into a second vehicle in the collision. For example, statewide cable barrier successfully restrained 95 percent of errant vehicles without involving a second vehicle, compared to only 67 to 75 percent of crashes with W-beam guardrail and concrete barrier. The study also found that the percentage of median crashes that result in injury or death is significantly lower for cable barrier (16 percent) than for W-beam guardrail (41 percent) and concrete barrier (41 percent), while the percentage of disabling and fatal crashes (the least frequent but most serious type of crash) is lower for concrete barrier (2.1 percent), followed by cable barrier (2.6 percent), and W-beam guardrail (4.4 percent).

WSDOT also analyzed collisions that involve motorcycles hitting the median barrier, and found that there was no significant difference in injury severity regardless of what type of median barrier was struck, although it should be noted that there were no instances of motorcyclists striking a cable barrier during the period under review.

The FARS database for the year 2003 showed that 19 percent of the head-on crashes which occurred on Interstates and expressways were on a divided highway median with a traffic barrier installed. From these data it is unlikely to say that barriers can eliminate crossover median head-on crashes. However, proper barrier selection is important to reduce the severity of these crashes. In selecting the median barrier, it is important to consider the lateral deflection characteristics of the barrier. The maximum deflection should always be less than one-half the median width to avoid penetrating into the opposing lane.

FHWA reports that the selection of a median barrier depends on various factors such as traffic volume, speed limits, traffic vehicle mix, median width, cross slope, number of lanes, roadway alignment, history of previous crashes recorded, and installation and maintenance costs. As a rule, the initial cost of a system increases as rigidity and strength increase, but repair and maintenance costs usually decrease with increased installation costs. Historical crash records should be reviewed to ensure that median barrier types requiring high maintenance and repair costs after every crash are avoided in high-crash locations.

Selection guidelines for median barriers are provided in the AASHTO *Roadside Design Guide*. In general, the most desirable system is one that satisfies performance requirements at the least total life-cycle cost. Appendix 3 provides a comparison of several manufacturers' cable barrier systems.

Special consideration should be given when considering a barrier for medians separating traveled ways at different elevations. The ability of an errant driver leaving the higher roadway to return to the road or to stop diminishes as the difference in elevation increases. In such cases there is an increased probability of a cross-median head-on collision occurring.

Median can either be symmetrical or asymmetrical based on the physical conditions of the terrain. In level terrain symmetric medians are common, and in rolling or mountainous terrain asymmetric medians may be needed due to topography or environmental constraints.

Terrain conditions can have a significant effect on the barrier's impact performance. For example, slopes and drainage swales in the median can cause a vehicle's suspension to compress, or impart a roll moment to the vehicle, which may result in the vehicle going over or under the barrier, or snagging on the support posts of a strong post system. As noted in the draft *Roadside Design Guide*, further research is planned to quantify possible placement concerns when a rigid or semi-rigid barrier is located on one side of a traversable, sloped median.

Since most reported penetrations have involved passenger vehicles with relatively low front profiles impacting at high speeds and high angles, it is not considered cost-effective to reposition existing cable barrier that has been installed within this area unless a recurring crash problem is evident. However, in the state of Washington, where there is evidence of an increasing number of crashes and a large number of crossover collisions on a 10-mile stretch of the I-5 near Marysville, WSDOT is proposing to install a second run of cable barrier on the other side of the median ditch to engage vehicles before they bottom out in the ditch and lift the cable barrier.

Redirecting small vehicles with little risk of injuring the occupant in a collision is certainly an advantage, but it may also cause a problem if the errant vehicle returns to the fast moving traffic lane. Certainly there is a balance between minimizing the severity of the initial barrier collision and returning the vehicle to the traveling lane where it may get involved in a possibly more serious collision.

Not only the installation of the median barrier, but also the maintenance of the median barrier is relatively important, since median barriers such as the three-cable barrier, in some cases, become less effective after every collision. In some cases, periodic re-tensioning of the cables is necessary for its effective performance. It is likely that sometimes a barrier may be struck but the colliding vehicle may not incur much damage. The driver may simply leave and continue on the highway without notifying authorities. For this reason it is prudent to periodically check barrier systems as occurrences may go unnoticed for long periods of time.

EXHIBIT V-13
Strategy Attributes for Use of a Median Barrier (P)

Attribute	Description																																				
Technical Attributes																																					
Target	Drivers who unintentionally cross the median.																																				
Expected Effectiveness	<p>NCDOT in Stasberg and Crawley 2005 reports that the installation of median barriers has resulted in:</p> <ol style="list-style-type: none"> 1. An estimated 90 percent reduction in freeway cross-median crashes. 2. Approximately 25 to 30 lives saved each year. 3. Hundreds of injuries prevented or reduced each year. <p>An estimated savings of millions of dollars in crash costs annually. Below are sample installations of median guardrails in North Carolina.</p>																																				
	<table border="1"> <thead> <tr> <th style="text-align: left;">Location</th> <th style="text-align: center;">Length (Miles)</th> <th style="text-align: center;">Cross-Median Crashes per Year before Installation</th> <th style="text-align: center;">Cross-Median Crashes per Year after Installation</th> <th style="text-align: center;">Fatal Cross-Median Crashes per Year before Installation</th> <th style="text-align: center;">Fatal Cross-Median Crashes Per Year after Installation</th> </tr> </thead> <tbody> <tr> <td>I-26 from Buncombe County Line To MM 23.8 and Green River to Polk County Line</td> <td style="text-align: center;">16.48</td> <td style="text-align: center;">7.54</td> <td style="text-align: center;">0.32</td> <td style="text-align: center;">0.56</td> <td style="text-align: center;">0.00</td> </tr> <tr> <td>I-40 from SR 1138 to 0.201 miles west of US 64</td> <td style="text-align: center;">6.809</td> <td style="text-align: center;">3.96</td> <td style="text-align: center;">0.00</td> <td style="text-align: center;">0.55</td> <td style="text-align: center;">0.00</td> </tr> <tr> <td>I-40 from US 70 to 1.0 mile east of US 221</td> <td style="text-align: center;">13.94</td> <td style="text-align: center;">5.58</td> <td style="text-align: center;">0.00</td> <td style="text-align: center;">0.56</td> <td style="text-align: center;">0.00</td> </tr> <tr> <td>I-95 Bus from 250' south of Cross Creek Bridge to 1060' north of US 301</td> <td style="text-align: center;">5.00</td> <td style="text-align: center;">3.15</td> <td style="text-align: center;">0.00</td> <td style="text-align: center;">0.30</td> <td style="text-align: center;">0.00</td> </tr> <tr> <td>I-40 from Johnston County Line to Pender County Line</td> <td style="text-align: center;">20.19</td> <td style="text-align: center;">5.18</td> <td style="text-align: center;">0.67</td> <td style="text-align: center;">0.14</td> <td style="text-align: center;">0.00</td> </tr> </tbody> </table>	Location	Length (Miles)	Cross-Median Crashes per Year before Installation	Cross-Median Crashes per Year after Installation	Fatal Cross-Median Crashes per Year before Installation	Fatal Cross-Median Crashes Per Year after Installation	I-26 from Buncombe County Line To MM 23.8 and Green River to Polk County Line	16.48	7.54	0.32	0.56	0.00	I-40 from SR 1138 to 0.201 miles west of US 64	6.809	3.96	0.00	0.55	0.00	I-40 from US 70 to 1.0 mile east of US 221	13.94	5.58	0.00	0.56	0.00	I-95 Bus from 250' south of Cross Creek Bridge to 1060' north of US 301	5.00	3.15	0.00	0.30	0.00	I-40 from Johnston County Line to Pender County Line	20.19	5.18	0.67	0.14	0.00
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Source: NCDOT

EXHIBIT V-13 (Continued)
 Strategy Attributes for Use of a Median Barrier (P)

Attribute	Description
	<p>South Carolina DOT (SCDOT) installed 315.5 miles of three-strand cable on Interstate segments with median widths less than 60 ft wide. In a 3-year period 1,913 vehicles were stopped by the barrier with 15 vehicles (i.e., 1 percent of the vehicles) penetrating the cable barrier. According to the study, cable median barriers were 99 percent effective in saving lives. Before the installation of the barrier in the period 1999–2000 more than 70 people lost lives in 57 separate Interstate median crashes (FHWA, 2003).</p> <p>In Oregon, on I-5, after the installation of three-cable barrier from December 1996 to March 1998 there were 53 barrier impacts and 21 potential crossovers which were restrained from entering the opposing traffic lanes. Three vehicles went through the cable barrier, though two of the vehicles did not cross over into the opposing lane. The third vehicle, a semi-truck, went through the cable barrier, crossing into the opposing traffic lane (<i>Research Notes</i>, 1998).</p> <p>In Kansas City, Missouri, a study on cable barrier that was installed along a 20-mile section of Interstate 435 showed that it had eliminated fatalities (Mason et al., 2001). During 1998 and 1999, 14 people were killed on the same section of highway by vehicles crossing the median. The Missouri Department of Transportation estimates that approximately 200 vehicles crash into the barrier each year. According to their data, the cable barrier installation project has proved to be extremely cost-effective. In addition to the elimination of fatalities, median crashes have tended to be much less severe. Several other locations are now being considered for this median treatment.</p> <p>A November 2003 study carried out by the state of Washington (WSDOT) on the effectiveness of cable barrier found that after its installation the number and severity of cross-median crashes was significantly reduced. The review covered collision data for approximately 26.5 miles of the I-5, and found that on an annual basis the number of median-crossover crashes was reduced from 16 to approximately 4 and the number of fatal and disabling crashes in the median was reduced from 6.6 to approximately 2.0 (WSDOT, 2006).</p> <p>WSDOT also evaluated the relative effectiveness of different types of median barriers by analyzing 11,457 median barrier collisions that occurred on their state highways between 1999 through 2004. Excluding a portion of the I-5 in Marysville, where factors not present elsewhere were influencing the performance of the cable barrier, the analysis indicated that occupants of vehicles striking cable barrier were less likely to be injured or killed than those striking concrete barrier or guardrail. For example, the percentage of median crashes resulting in injury or death is significantly lower for cable barrier (16 percent) than for concrete barrier (41 percent) or W-beam guardrail (41 percent), and all potential injury crashes are included from “possible Injury” to “Disabling Injury.” A summary of the barrier performance by injury severity is shown below:</p>

Barrier Performance by Injury Severity

Barrier Type	Total Number of Collisions	Injury Severity					Fatal
		Not Stated	No Injury	Possible Injury	Evident Injury	Disabling Injury	
Concrete barrier	7,585	114 (1.5%)	4,345 (57.3%)	1,901 (25.1%)	1,061 (14.0%)	130 (1.7%)	34 (0.4%)
W-beam guardrail	2,579	52 (2.0%)	1,468 (56.9%)	532 (20.6%)	412 (16.0%)	73 (2.8%)	42 (1.6%)
Cable, without I-5 Marysville	152	6 (3.9%)	121 (79.6%)	14 (9.2%)	7 (4.6%)	4 (2.6%)	0 (0%)

EXHIBIT V-13 (Continued)

Strategy Attributes for Use of a Median Barrier (P)

Attribute	Description							
Barrier Performance by Injury Severity (Continued)								
Barrier Type	Total Number of Collisions	Injury Severity			Possible Injury	Evident Injury	Disabling Injury	Fatal
		Not Stated	No Injury					
Cable, with I-5 Marysville	171	3 (1.8%)	132 (77.2%)	11 (6.4%)	17 (9.9%)	3 (1.8%)	3 (1.8%)	
All cable barrier	323	9 (2.8%)	253 (78.3%)	25 (7.7%)	24 (7.4%)	7 (2.2%)	5 (1.5%)	
Bridge rail	970	14 (1.4%)	608 (62.7%)	197 (20.3%)	126 (13.0%)	21 (2.2%)	4 (0.4%)	
Total	11,457	189 (1.6%)	6,674 (58.3%)	2,655 (23.2%)	1,623 (14.2%)	231 (2.0%)	85 (0.7%)	

Washington State Highways, 1999–2004

Ignoring the I-5 Marysville crashes, the study found that collisions with cable barrier were significantly less likely to involve multiple vehicles than guardrail and concrete barriers. Also, less than half as many injuries and fatalities occur when a single vehicle collides with cable barrier compared to guardrail or concrete barrier. When multiple vehicles are involved in a collision, the injury rate for all barrier types is comparable, as indicated below:

Average Number of Injuries and Fatalities Per Collision

	Concrete Barrier	Beam Guardrail	Cable Barrier
Single vehicle collisions	0.47	0.45	0.19
Multi-vehicle collisions	0.81	0.89	0.88

Note: Cable barrier data does not include I-5 Marysville.

Washington State Highways, 1999–2004

In terms of vehicles going beyond a median barrier, WSDOT found that, overall, 1 percent of errant vehicles that hit concrete barrier go beyond the barrier compared to 4 percent for guardrail and 5 percent for cable barrier (not including the I-5 in Marysville).

Appendix 4 illustrates several states' cable median barrier case studies.

Keys to Success

Median barriers are an effective safety solution for median-crossover crashes. The variety of median barriers available makes it easier to choose a site-specific solution. The main advantage is the reduction of the severity of the crashes. The key to success would be in selecting an appropriate barrier based on the site, previous crash history, maintenance needs, and median width.

Median barriers are categorized as flexible, semi-rigid, or rigid. The AASHTO *Roadside Design Guide* includes descriptions and performance capabilities of crashworthy median barrier systems that have met the criteria of *NCHRP Report 350*. In general, a standard barrier meeting Test Level 3 (TL-3) criteria is capable of redirecting passenger cars and

EXHIBIT V-13 (Continued)
 Strategy Attributes for Use of a Median Barrier (P)

Attribute	Description
	<p>light vans and trucks adequately. Research in Florida, for example, indicated that in only two percent of the “across-median” crashes investigated was the crossing vehicle larger than a passenger car. However, at locations with adverse geometry, high traffic volumes and speeds, or a significant volume of heavy truck traffic, higher performance level median barriers may be considered. The <i>Roadside Design Guide</i> identifies and describes median barriers meeting TL-4 or higher, which have an increased capability to contain and redirect large vehicles.</p> <p>The <i>Roadside Design Guide</i> provides direction for when a particular system should or should not be considered. Weak post W-beam and Box-Beam median barriers should be used only in relatively flat, traversable medians. Terrain irregularities can increase the likelihood of a vehicle going over or under the rail if the bumper height at impact is in a range that is higher or lower than within normal design ranges. Similarly, cable barrier should be used only where adequate deflection distance exists to accommodate significant movement of the barrier. (See FHWA acceptance letters for deflection distances noted in manufacturers’ certification testing at http://safety.fhwa.dot.gov/roadway__dept/roadHardware/index.htm.) Conversely, concrete barrier typically undergoes little or no deflection, and may thus be more suitable where space is very limited.</p>
Potential Difficulties	<p>The increased use of median barrier does have some disadvantages. These include the initial cost of installation and the likely increase in the number of reported collisions associated with the reduced availability of a recovery area. After the installation of the barrier, crash severity may decrease but crash frequency may increase. By placing the barrier, vehicle recovery space is reduced and the vehicles which could have recovered if the barrier was not present may crash with the barrier. A before and after study by Seamons and Smith (1991) found a total increase of roughly 14 percent in all injury accidents when median barriers were installed at freeway locations.</p> <p>The latter will also result in ongoing barrier repair costs and an increased exposure of maintenance crews to traffic. Additionally, the barrier will limit the options of maintenance and emergency vehicles to cross the median, and may affect the ability to store snow in the median.</p> <p>Concrete barriers are very costly to implement but require minimum maintenance. These may also require modification of drainage structures and specialized construction equipment and personnel for installation. The three-strand cable median barrier, which is widely used, may require a higher level of maintenance but the installation costs are relatively less, since it requires periodic re-tensioning of the cables and may need adjustment each time the barrier is struck.</p>
Appropriate Measures and Data	<p>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, which is 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.</p> <p>The strategy will be most effective when data and an analysis methodology exist to target the implementation of the most appropriate sites—a methodology that identifies sites based on head-on rather than total crashes.</p>

EXHIBIT V-13 (Continued)

Strategy Attributes for Use of a Median Barrier (P)

Attribute	Description
Associated Needs	As the drivers are familiar with the barriers, there doesn't appear to be a need for any public information and education initiative.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	<p>These strategies will be implemented by state and local roadway agencies, and it doesn't appear that extra coordination with other agencies or groups is needed.</p> <p>If the state does not have a policy defining the 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 <i>Roadside Design Guide</i>. Such warrants may need to be adjusted or refined according to local state needs and studies. In considering the improvement of design and application systems, reference to the AASHTO <i>Roadside Design Guide</i>, Chapter 6, is important.</p>
Issues Affecting Implementation Time	This strategy would in many cases be possible to implement within a 1- to 3-year period after site selection. Barrier design and placement within the existing narrow median would require no right-of-way, a minimal environmental process, and generally one construction season.
Costs Involved	<p>Costs will vary depending on the type of median barrier selected and also 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, <i>NCHRP Synthesis 244</i> summarizes survey results of 39 states to quantify the typical installation cost for roadside and median barriers. (For more details see <i>NCHRP Synthesis 244</i>, Ray and McGinnis, 1997).</p> <p>A study in Washington indicated that the installation cost for the cable barrier was found to be approximately \$42,000 per mile and the repair costs were approximately \$4,250 per mile per year. Using WSDOT Unit bid history (McClanahan et al., 2004), the state average bid prices for different barriers (cost of barrier only) were found to be:</p> <p>Cable median barrier—\$44,000/mile W-beam guardrail—\$72,000/mile Precast concrete barrier—\$130,000/mile Single-slope concrete barrier—\$237,000/mile Cast-in-place concrete barrier—\$419,000/mile</p> <p>When evaluating the cost-effectiveness of a particular type of a 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. It is also important to consider appropriate attenuation systems—refer to the AASHTO <i>Roadside Design Guide</i>, Chapter 6.</p>

EXHIBIT V-13 (Continued)
Strategy Attributes for Use of a Median Barrier (P)

Attribute	Description																																																												
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Training and Other Personnel Needs	Maintenance staffs require training in the proper installation and repair of barrier systems.																																																												
Legislative Needs	None identified.																																																												
Other Key Attributes																																																													
Compatibility of Different Strategies	See discussion of slope.																																																												
Other Key Attributes to a Particular Strategy	None identified.																																																												

Strategy 18.2 B4—Implement Channelization, Signing and Striping Improvements at Interchanges Susceptible to Wrong-Way Movements (T, E)

Not all head-on crashes on freeways are attributable to median-crossover encroachments. Some portion may occur as a result of drivers who make wrong-way entries onto freeways. Wrong-way driving often leads to head-on collisions. Although wrong-way crashes are

relatively infrequent, they are more likely to produce serious injuries and fatalities compared to other types of freeway crashes.

Statistics from the Fatality Accident Report System (FARS) database for the 5-year period between 1996 and 2000 indicated that approximately 350 people are killed each year in wrong-way crashes on U.S. freeway facilities (on ramps and main line) (Moler, 2002). It has also been reported that out of every 100 wrong-way crashes, 62.7 result in an injury or fatality, compared to 44.2 out of 100 for all freeway and expressway crashes (Tamburri and Theobald, 1966).

A recent study by the Texas Transportation Institute on the issue of wrong-way driving on freeways in Texas included a state-of-the-practice literature review, which suggested the following profile (Cooner et al., 2004):

- The most frequent origin of wrong-way incidents is the freeway exit ramp (i.e., a driver travels the opposite direction on an exit ramp onto the freeway main lanes).
- Crashes tend to be more severe and have a greater proportion resulting in death or serious injury than most other crash types on freeway facilities.
- Elderly drivers are over-represented compared to their proportion of the driving population and their proportion of involvement in other crashes.
- Male drivers are significantly more likely to be involved than female drivers.
- Between 50 and 75 percent involve an impaired wrong-way driver who had been drinking or was under the influence of alcohol or drugs.
- Crashes are more prevalent during non-daylight hours, particularly the early morning hours following midnight.

Research into wrong-way movements on freeways in the Netherlands, based on official police reports, showed that about one-half of the incidents of wrong-way driving started when drivers entered freeway exit ramps, while the remainder started when drivers turned their vehicles around (mainly on the main line) or engaged in similar maneuvers. Entering exit ramps occurred predominantly during darkness and typically involved drivers aged 55 and older, who apparently had a problem processing visual and other information properly near the ramp heads. Turning around was primarily done by younger drivers, who generally started wrong-way driving deliberately to correct a previous mistake in their route planning.

In addition to the state-of-the-practice research literature noted above, the Texas study surveyed state DOTs to gather information on typical wrong-way signing and marking plans and any innovative practices or countermeasures they used. In general, most DOTs used the standard “Do Not Enter” (DNE) and “Wrong Way” (WW) signs and “Wrong Way” pavement arrows from the *Manual on Uniform Traffic Control Devices* (MUTCD) (U.S. DOT, 2003). The researchers also identified and evaluated the feasibility and applicability of available countermeasures and treatments, documented typical situations that were likely to produce wrong-way entry issues, developed guidelines and recommended practices for the application of wrong-way countermeasures and treatments, and developed a checklist for engineers and field crews to use for reviewing wrong-way entry issues or suspected problem locations. Further details of the research project, including guidelines and recommended practices, can be found at: <http://tti.tamu.edu/documents/0-4128-1.pdf>.

Strategies that are directed at preventing wrong-way movements range from relatively inexpensive, such as signing and pavement marking, to very costly, such as intelligent transportation system (ITS) applications. Typically, countermeasures and treatments to mitigate wrong-way entries fall under four categories:

- Traditional signing and pavement marking
- Innovative signing and pavement marking
- Geometric modifications
- ITS applications (see Exhibit V-14)

As noted in the Texas study, traditional signing and pavement marking countermeasures include “DNE and WW signs on separate posts, oversized DNE and WW signs, red-backed raised pavement markers, WW pavement arrows, yellow edge lines on left sides of exit ramps, one-way signs, and turn restriction signs” (Cooner et al., 2004, p. 2).

Innovative signing and pavement marking treatments include lowered DNE and WW signs mounted together on the same post, supplemental placards or flashers on the DNE and WW signs, overhead-mounted DNE and WW signs, internally illuminated DNE and WW signs, non-standard WW pavement arrows, WW pavement lights, red reflective tape on the backs of freeway signs, and red delineators on each side of the ramp up to the WW signs. Exhibit V-15 shows an example of a lowered sign treatment.

Enhancements of the use of “Do Not Enter” and “Wrong Way” signs, and wrong-way pavement arrows, as described in the MUTCD should be considered; however, measures such as lowering the sign mounting height should be considered as well. Several studies have determined this to be an effective countermeasure, particularly as the signs tend to become more visible at night since they are in the path of low beam headlights, and they are also potentially more visible to impaired drivers because they tend to drive with their eyes low looking for visual clues from the pavement. The signs are typically placed with the bottom of the lower sign about 2 ft above the edge of the pavement, and located such that at least one sign package is visible in the area covered by the car’s headlights, and that they are

EXHIBIT V-14

Example of ITS Application to Indicate Wrong Way Movement

Source: Texas Department of Transportation



EXHIBIT V-15

Lowered Signs at Freeway Ramp

Source: Texas Department of Transportation

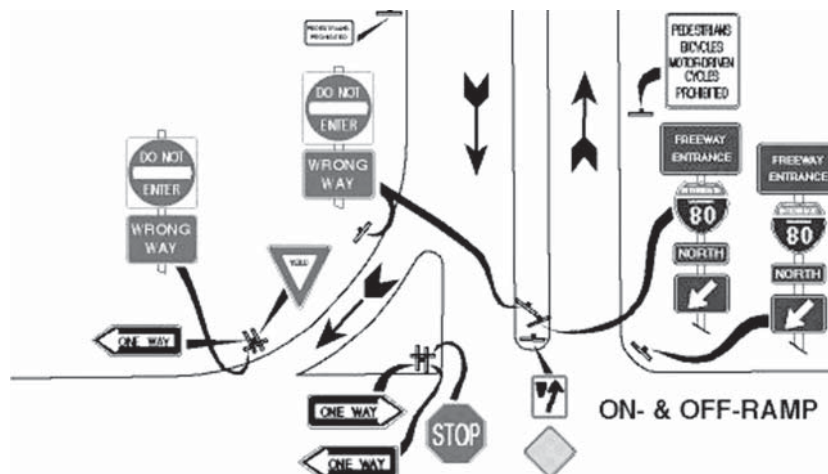


visible to the driver from the decision point on each likely wrong-way approach. California, Georgia, and Virginia are three states that have adopted this signing approach. In some cases, this guidance has been supplemented by other measures such as the use of oversized “Do Not Enter” signs for locations with recurring problems, the use of a second set of “Do Not Enter” and “Wrong Way” signs to give drivers another opportunity to rectify their mistake, or the use of two wrong-way arrows (reflectorized where appropriate). In 2005, the state of Ohio installed additional signs on ramps that could be mistakenly entered the wrong way, with a typical layout incorporating a pair of “Do Not Enter” signs near the throat of the ramp (one on each side of the ramp), a pair of double “Wrong Way” signs part-way down the exit ramp (one “Wrong Way” sign above another on each side of the ramp, with the lower one mounted about 1 ft above the pavement) and a pair of signs further down the ramp nearer to the ramp gore showing a “Do Not Enter” sign above a low-mounted “Wrong Way” sign. Red reflective tape was also applied to the sign posts to enhance nighttime visibility. Exhibit V-16 illustrates a typical signing and marking layout.

EXHIBIT V-16

Standard Freeway Signing and Marking Layout

Source: CALTRANS



Additional traffic control measures used by some states, and worthy of consideration, include the use of low mounted “One Way” arrow signs, the addition of a 24-in. wide painted stop bar at the crossroad end of the ramp, and supplementary “Ramp” and “Freeway” signs. Another important consideration is the maintenance of the measures that are in place to prevent wrong-way movements. Repair of deficient elements such as wrong-way pavement arrows (particularly where these consist of raised pavement markers which may become damaged or go missing) should be given priority, especially at known or suspected problem locations.

Certain interchange forms are more susceptible to wrong-way movements. The most common interchange form is a diamond; drivers understand, expect, and generally negotiate diamond interchanges properly. To enter the freeway from the crossroad at a diamond, the driver turns right before the crossing of the freeway, and left after the crossing.

Partial cloverleaf forms, in particular the certain applications of a ‘parclo A’ or ‘parclo AB’ may increase the potential for wrong-way movements. As shown in Exhibit V-16, such interchanges may be used where right-of-way is not available in one quadrant. The entry movement onto the freeway for a ‘right’ turn may be a left turn, and that entrance ramp may be adjacent to the exit ramp terminal. Inattentive drivers may turn into the wrong opening at such locations.

Geometric treatments for interchanges include offset entrance and exit ramps, particularly at interchanges where the terminals are closely spaced, and off-ramp throat reductions, where reducing the size of the opening by using curbs, delineator posts, and painted islands makes the wrong-way movement less inviting. Other measures to be considered include using small radii corners on either side of the throat, and using an island or painted median to divide parallel adjacent on- and off-ramps to discourage wrong movement.

Wrong-way entry checklists have been developed by some agencies for engineers and field crews to use for reviewing wrong-way entry issues or suspected problem locations. Appendix 5 contains a checklist produced by the Texas Transportation Institute based on one originally developed by Caltrans.

EXHIBIT V-17

Strategy Attributes to Implement Channelization, Signing and Striping Improvements at Interchanges Susceptible to Wrong-Way Movements (T, E)

Attribute	Description
<i>Technical Attributes</i>	
Target	Treatment will target locations where wrong-way movements and crash experience at interchanges is determined to be a problem. With respect to head-on crashes, the target is drivers who make wrong-way entries onto freeways.
Expected Effectiveness	While wrong-way crashes are relatively infrequent, they are more likely to produce serious injuries and fatalities compared to other types of freeway crashes. There have been a variety of measures developed to address this issue. Some of the measures are tried and many are experimental.

EXHIBIT V-17 (Continued)**Strategy Attributes to Implement Channelization, Signing and Striping Improvements at Interchanges Susceptible to Wrong-Way Movements (T, E)**

Attribute	Description
	<p>Ohio DOT in the Columbus area experienced 17 wrong-way crashes over a 2-year period (2004–2005). In 2005, additional signs were installed on ramps that could be easily entered by wrong-way maneuvers (diamond, trumpet, partial cloverleaf). The signs consisted of enhanced red background signs. Preliminary studies indicate that no wrong-way crashes have occurred through March 2006. This study is preliminary in nature due to potential regression to the mean and study period limitations.</p> <p>Several studies have determined the following to be potentially effective countermeasures: enhancements of the use of “Do Not Enter” and “Wrong Way” signs, wrong-way pavement arrows, and actions as described in the MUTCD such as lowering the sign mounting height.</p> <p>Other tried strategies include geometric treatments for interchanges with offset entrance and exit ramps; where the terminals are closely spaced, off-ramp throat reductions, reducing the size of the opening by using curbs; adding delineator posts; and painted islands to make wrong-way movement more difficult. Other tried measures to be considered include using small radii corners on either side of the throat, and using an island or painted median to divide parallel adjacent on- and off-ramps to discourage wrong movement. Studies of the effectiveness of these strategies are not available.</p>
Keys to Success	The use of wrong-way entry checklists developed by some agencies for engineers and field crews to use for reviewing wrong-way entry issues should be a first step in investigating a candidate site. Consideration of a variety of techniques ranging from traditional signing and pavement marking, innovative signing and pavement marking, geometric modifications, and ITS applications should be considered in at least an incremental manner by agencies according to resources.
Potential Difficulties	Various ITS applications are being used in a number of states including California, Florida, New Mexico, and Washington, with varying degrees of success. For example, trials with two dynamic wrong-way signing treatments in Washington were plagued with maintenance problems caused by vehicle detection systems and false alarms.
Appropriate Measures and Data	Data are needed on the nature of specific wrong-way traffic crashes. If possible it should be verified where the exact location of the identified wrong-way crash movement in question occurred. Data such as that collected and discussed in the Texas DOT study help to identify specific characteristics of crashes and assist in the identification and selection of countermeasures.
Associated Needs	As these types of crashes can be highly visible to the public and very severe in nature a good public information and education effort for the strategies implemented may be essential especially for nontraditional measures.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Wrong-way countermeasures are typically implemented by state DOTs and no coordination is required. A comprehensive set of design guidelines, typical drawings, and the development of a checklist may need to be implemented. These countermeasures may require cooperation within the agency, especially if these types of safety measures are tied to routine maintenance, traffic operations, and facility design.
Issues Affecting Implementation Time	Depends upon the treatment. Signing and operational treatments can be done quickly, but geometric improvements and ITS strategies require more time. Nevertheless, all strategies being suggested should have relatively short implementation periods.

EXHIBIT V-17 (Continued)

Strategy Attributes to Implement Channelization, Signing and Striping Improvements at Interchanges Susceptible to Wrong-Way Movements (T, E)

Attribute	Description
Costs Involved	Highly variable depending upon the specific treatment and extent. Signing and marking countermeasures are low cost in nature. Geometric modifications and ITS related strategies are more costly but could be considered intermediate in nature.
Training and Other Personnel Needs	No special personnel needs for implementing this strategy. Either agency personnel or contractors could implement. For ITS strategies, training may be necessary for new technologies.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	None Identified.
Other Key Attributes to a Particular Strategy	None identified.

Objective 18.2 C—Reduce the Severity of Median Barrier Crashes That Occur

This section includes a strategy aiming at the likelihood of reducing the severity of the crash rather than preventing the crash. Strategies that are directed at roadside design range from very costly to relatively inexpensive. The former include purchasing new right-of-way, building wider clear zones where limited zones now exist, and clearing and grading clear zones on right-of-way already owned. Less costly strategies may include replacing non-breakaway or outdated roadside hardware with newer technology at selected locations. In considering this strategy, reference should be made to the AASHTO *Roadside Design Guide*.

Strategy 18.2 C1—Improve Design and Application of Barrier and Attenuation Systems (T)

When a vehicle leaves the roadway and hits an untreated end of a roadside barrier or a fixed object, it may lead to a severe crash. Sometimes the barrier elements may penetrate into the vehicle or sometimes may cause a rollover. The crash may be severe if the vehicle traveling at a high speed comes to an abrupt stop. To avoid these types of crashes the best method would be to clear all the objects in the clear zone area, but this may not always be possible. When a barrier needs to be installed in the median proper, barrier treatments or crash cushions are used to reduce the severity of impact of these types of crashes.

The clear zone concept entails removal or elimination of objects from the clear zone that can result in crashes. However, it is often impractical to eliminate all such objects. These include the following: hardware or objects related to traffic guidance or control (such as

signs or some lighting supports), placement of objects serving as protection from more hazardous immovable objects or situations (including guardrails and median barriers), roadway design requirements (such as culverts), and traditional right-of-way uses (including utility poles and mail boxes). Regardless of the reason, the best treatment for all objects is to remove them from the zone. If this cannot be done, alternative strategies include the following:

- Relocating the objects either farther from the traffic flow or to less hazardous locations (e.g., relocating utility poles from the outside to the inside of horizontal curves).
- Shielding or replacing “harder” objects with less hazardous breakaway devices (e.g., use of breakaway street light supports, or use of crash cushions in front of hazardous immovable objects).

The AASHTO *Roadside Design Guide* includes detailed discussion of this overall “forgiving roadside” strategy, along with design specifications, placement information and crash test results for a large number of roadside hardware devices. The guide also includes criteria for use in determining which of the many alternative hardware types should be chosen for a specific application.

A final strategy for improving roadside hardware involves replacing less forgiving, older hardware with newer designs. The *Roadside Design Guide* is also a useful reference in this context, since it provides effectiveness information on both older and newer hardware designs.

The *Roadside Design Guide* provides general direction for a number of different types of hardware regarding when an older, outdated piece of hardware should be replaced. The *Roadside Design Guide* advises that “the number of fixed-object fatal crashes involving traffic barriers is exceeded only by fatal crashes with utility poles and trees.” One possible explanation for the number of barrier-related fatalities is the fact that many older installations do not always meet currently recommended performance levels. “More detailed guidance is given for roadside barriers. The primary criterion is whether the older barrier meets “current structural guidelines” (based primarily on crash test results) or whether it meets “current design and location guidelines” (too short to protect the hazard or too close to the hazard, based upon barrier deflection characteristics) (AASHTO, 2002, p. 5–37).

NCHRP Report 350 contains recommendations for testing the performance of the barrier treatments and crash cushions. To be acceptable for installation, the devices must meet the evaluation criteria set forth in the report.

Crash cushions or impact attenuators are protective devices that prevent errant vehicles from striking the fixed objects; their main function is to decelerate the vehicle to stop or to re-direct the vehicle to its travel direction. They basically work on two principles: the kinetic energy principle and the conversion of momentum principle.

Additional details concerning current practice with barrier terminals and crash cushions can be found on FHWA’s “Roadside Hardware” website, which provides information on acceptance of different types of barrier terminals and crash cushions. See http://safety.fhwa.dot.gov/roadway_dept/road_hardware/index.htm for more information.

EXHIBIT V-18

Strategy Attributes for Improved Design and Application of Barrier and Attenuation Systems (T)

Attribute	Description
Technical Attributes	
Target	<p>The target for this strategy is existing safety hardware (guardrail terminals, impact attenuators, and barriers) that can be improved:</p> <ul style="list-style-type: none"> • Hardware that is outdated (does not meet <i>NCHRP Report 350</i> crash test criteria). Guardrail terminals, in particular, should be evaluated. • Hardware that is damaged or in poor condition. • Installation improvements such as flatter approach slopes, barrier height, deflection space, and barrier length. <p>Opportunities should also be investigated for where fixed objects can be removed, relocated, or made breakaway.</p>
Expected Effectiveness	<p>Safety hardware that meets current crash test criteria and is properly designed, constructed, and maintained will reduce the severity of crashes. Many newer systems have energy absorbing capabilities that can gradually decelerate or smoothly redirect an errant vehicle and reduce the risk of a serious crash.</p>
Keys to Success	<p>As system-wide improvements may be cost prohibitive, locations should be prioritized and improvements made where they will have the greatest impacts—Interstates and other routes with high traffic volumes and high speeds, installations that are being impacted frequently, and locations where run-off-the-road crashes are more likely (such as horizontal curves). A program where safety hardware is periodically upgraded as a part of 3R projects is also recommended.</p>
Potential Difficulties	<p>Field inspection will be required to inventory what types of systems are currently installed, what systems need to be upgraded, what problems need to be addressed, and the location.</p>
Appropriate Measures and Data	<p>In-service performance evaluation of safety hardware is important for understanding how well systems are functioning. Ensuring that systems meet current crash test criteria is important but validating performance in real-world conditions is also important.</p>
Associated Needs	<p>None identified.</p>
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	<p>Creating an inventory/database (perhaps GIS-based) of safety hardware installed in the field would be a useful tool for identifying system types, how long they've been in service, and prioritizing what systems should be inspected and upgraded.</p>
Issues Affecting Implementation Time	<p>The main issue affecting implementation would be the time to identify and prioritize the systems and locations to upgrade.</p>
Costs Involved	<p>Costs to acquire and construct new safety hardware. Costs to repair or adjust existing hardware. Costs associated with removing or relocating fixed objects. Minor grading may be required to improve approach slopes or the flat area required around guardrail terminals. There will also be data collection and design costs. Ideally, in-service performance data will also be gathered.</p>
Training and Other Personnel Needs	<p>Training for the personnel that will inspect existing safety systems, so that they can identify the type of system, potential problems, and potential improvements.</p>
Legislative Needs	<p>None identified.</p>

EXHIBIT V-18 (Continued)

Strategy Attributes for Improved Design and Application of Barrier and Attenuation Systems (T)

Attribute	Description
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	This strategy is compatible with and complementary to the other strategies presented in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Objective 18.2 D—Enhance Enforcement and Awareness of Traffic Regulations

Strategy 18.2 D1—Designate “Highway Safety Corridors” (T)

Agencies experiencing significant cross-median collisions on a freeway or expressway corridor may sometimes choose an expensive infrastructure solution such as median barrier placement. It may be, however, that the cross-median collisions are symptoms of other problems unique to the corridor or location. Evidence of this may come from a review of the traffic volume and geometry of the problem corridor compared to other similar locations in the state. Understanding why one corridor experiences cross-median collisions when other comparable roadways do not may require more in-depth study, but such an effort may lead to more effective and less costly solutions than, for example, median barrier placement.

For any number of reasons, some stretches of roadway appear more challenging to drive. The reasons may relate to their location, climate, the local driving population, or other factors not directly related to roadway design. As a consequence, these roadways may experience a high rate of severe motor vehicle collisions such as cross-median collisions, serious injuries and fatalities. One strategy that may be considered to address these roadways is to designate the facility as a “Highway Safety Corridor,” and apply more frequent enforcement, low-cost engineering improvements, and education efforts to enhance safety along the corridor. The concept of safety corridors gained popularity after the FHWA listed it in 1990 as one of the five most promising short-term safety programs in the country.

Strategy 18.1 D1 takes the concept of highway safety corridors applied to the problem of cross-median collisions and fatalities. While this concept may apply to any highway, it may be particularly valuable in the context of higher volume freeways or expressways with a known or developing history of serious cross-median collisions. Agencies need to understand the fundamental reasons for the driving behaviors that create this problem, particularly where the roadway design features (such as alignment or cross section) appear to not explain the reasons for the problem.

A number of states, including California, New Jersey, New Mexico, Oregon, Pennsylvania, Virginia, and Washington, have established highway safety corridors. Appendix 6 contains an example of the Oregon Highway Safety Corridor Program. Although each state has its own set of regulations and requirements to designate a safety corridor, they all have the same objective

of reducing the number of collisions, injuries, and fatalities on the highway. Typically though, the common factors used to establish a safety corridor are safety history and community support. Candidates for designation are those corridors with crash rates significantly above the statewide average for the type of fatality, thus ensuring that valuable resources are being directed to address the most persistent safety problems, and also those corridors where there is extensive community support. The latter may include commitment by local law enforcement to increase patrols on the corridor by a specific amount, or an undertaking by local media outlets to increase public service announcements and news features about the corridor. Other factors that may be part of the selection criteria include traffic volume, safe conditions for enforcement capability, and the manageable length of corridor.

For example, selection criteria in the state of Oregon include a requirement for the 3-year average of the fatal/serious injury crash rate for the subject corridor to be at or above 110 percent of the 3-year state average for similar types of highway. A further condition is for state and/or local enforcement agencies to commit to making the corridor a priority patrol by providing a minimum of 50 additional regular enforcement hours per month. In addition, the length of corridor needs to be manageable from an enforcement and education point of view, which in Oregon is typically between 4 and 30 miles. Other requirements include commitments towards improving highway engineering along the corridor (for example, by reviewing the roadside safety elements along the corridor and carrying out periodic reviews to ensure that traffic control devices are compliant with current standards) and implementation of an education program to provide information about the safety corridor to the driving public.

Typically, the final decision on designating a corridor lies with a review panel, which screens candidate locations based on the established criteria.

A summary of the designation criteria used by various states for corridor selection, as well as for reviewing and decommissioning of corridors, is provided in a review paper entitled “Highway Safety Corridors Reduce Motor Vehicle Injuries and Fatalities—A Review of Initiatives in the U.S. and B.C.” (Truck Safe, 2005).

Enforcement is likely the single most effective short-term tool in reducing traffic crashes in safety corridors, and all current highway safety corridors have some form of enhanced law enforcement. This enforcement typically includes increased fines for moving violations such as speeding, tailgating, and improper lane changing. For example, Oregon and California double moving violation fines within safety corridors, and Virginia has maximum fines of \$500 for speeding and \$2,500 for reckless driving and driving under the influence. States such as North Carolina and Washington have, however, provided enhanced enforcement but not increased fines in safety corridors.

Education initiatives typically involve public information efforts such as media events, brochures, billboards, poster distribution, local presentations, and the like. Other components include corridor roadway signs alerting drivers to the designated corridors and informing them of the fine structure.

It follows that the success of a highway safety corridor program depends largely upon the cooperation of the participant groups such as state and local governments, enforcement agencies, regulatory agencies, media outlets, community organizations, and other stakeholder groups. Successful programs also need to have a review process in place to measure the effectiveness of the corridor and to ensure they achieve their objectives. In conjunction with the review process, it is also important to have a mechanism in place to decommission a safety corridor when the problem roadway shows improvement over a period of time and

is no longer required. For example, in the state of Oregon, once a safety corridor's 3-year fatal/serious injury crash rate drops below 110 percent of the state average, then the corridor is decommissioned unless a local stakeholder group "adopts" the corridor at their own expense and continues to provide a meaningful local level of resources. By decommissioning the corridor, critical resources can then be redirected to other corridors where the need is greatest. On the other hand, if periodic reviews indicate that the safety corridor is not improving safety, other measures should be considered.

Research carried out by Fontaine (2003) concluded that safety corridors have had mixed results, ranging from no effect to a reduction of up to 30 percent in total crashes, with part of the ambiguity of the impacts of safety corridor programs attributed to the need for better analytical methods to assess the effectiveness of safety corridors. Fontaine noted that evaluation of three sites by Caltrans indicated that the overall crash rate declined by 11 to 37 percent, and the rate of fatality or injury crashes declined by 13 to 47 percent. However, since only 1 year of crash data was analyzed after the implementation of the program, it was not possible for Caltrans to make a definitive assessment of the program's effectiveness because the reduction could simply be due to the random variation in crashes.

Similarly, data on the effectiveness of safety corridors in Oregon was somewhat limited, though Oregon DOT (ODOT) noted that total crashes had decreased in 7 of 12 corridors and, based on 1 year of post-implementation data, fatalities had decreased in 10 of 12 corridors. In the state of Washington, analysis of crash data from the 3 years following the implementation of a safety corridor program indicated a 9 to 30 percent reduction in crashes compared to the 3-year period prior to the program's implementation. However, as noted by Fontaine, a degree of caution needs to be considered when interpreting the findings, as changes in crash rates often cannot be attributed solely to the impact of the safety corridor program, and other factors may have influenced the results.

More recently, the Virginia Department of Transportation (VDOT) has reported back on their findings for two safety corridors established in Virginia. The first corridor, established in 2004, is on a 15-mile stretch of Interstate 81, which was exhibiting an increasing number of crashes between 2000 and 2003. In its first year of operation, the number of crashes along the corridor stayed about the same as the pre-implementation year. Telephone surveys suggested that there was high awareness of the safety corridor amongst the public, and 40 percent of those interviewed who were aware also said they had improved their driving behavior as a result. This increased awareness and change in behavior may be contributing to the 29 percent decrease in crashes along the corridor recorded in its second year, 2005. It should be noted that there was one run-off-the-road fatality crash recorded in 2005, while there had been no fatality crashes in the preceding 5 years. In terms of enforcement, 1,148 vehicles were cited for speeding and 269 for reckless driving in the I-81 corridor during 2005.

The second corridor, a 13-mile section of Interstate 95, was established in 2005, and this exhibited a 13 percent reduction in total crashes and a 17 percent reduction in injury crashes during the first year of operation. There were, however, four fatality crashes during 2005, two of which involved pedestrians crossing I-95. This compares to an average of 1.6 fatalities per year over the preceding 5 years. In terms of enforcement, 1,185 vehicles were cited for speeding and 1,581 for reckless driving in the I-95 corridor during 2005.

In summary, studies conducted by various states suggest that the concept of a highway safety corridor has the potential to improve safety in "high crash" corridors, particularly in the short term. However, it should be recognized that post-implementation data are

somewhat limited in many cases, and therefore any observed reductions in crashes may be due to other reasons, or simply due to the random variation in crashes. Also in some cases, no measurable safety improvement has been recorded. It is likely, though, that safety corridors will probably have the largest impact when a strong collaborative approach is committed to by the various stakeholders, and where resources are available to increase enforcement, provide educational measures, and implement engineering countermeasures.

There is also little information available about the performance of the highway after the decommissioning of the safety corridor, so it is unclear whether crashes will increase once the increased enforcement and education programs are removed. As such, the highway safety corridor may really be providing a relatively cheap short-term solution to address a serious collision problem, while allowing additional time for the highway agency to develop more permanent safety improvements and obtain funding for such improvements. Consequently, although results to date suggest that highway safety corridors are beneficial in reducing crashes, it is likely too soon to consider the program as proven.

More importantly, none of the studies refer specifically to the effect of highway safety corridors on reducing head-on type collisions, but rather on the effect upon total crashes. Therefore, while the implementation of a safety corridor has the potential to reduce head-on type crashes by helping to reduce speeding, raise driver awareness, and modify driving behavior, the strategy as a measure to reduce head-on type collisions is unproven at this time.

Strategy 18.2 D2—Conduct Public Information and Education Campaigns (T)

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 area-wide campaigns, use of roadside signs and other experimental methods may be tried on a pilot basis.

There are several ways to increase public awareness such as using the local newspaper, television, radio, and the internet. Radio and the news on television would be the best ways to communicate the information. As discussed in *NCHRP Report 500, Volume 1: A Guide to Addressing Aggressive-Driving Conditions*, radio is probably the best method to communicate to drivers. Radio also can target a diverse demographic audience if aired on a variety of radio stations. Television has an advantage over radio, particularly because visuals such as high-speed dramatizations can be viewed. Group meetings are another method of campaign; the advantage of this approach is that the public can also get involved in the campaign.

Objective 18.2 E—Improve Coordination of Agency Safety Initiatives

Strategy 18.2 E1—Enhance Agency Crash Data Systems (T)

For planning safety measures, accurate crash data along with periodic updating are required. Updated information regarding the geometric conditions of the roadway is essential. Each state maintains their traffic data and the quality of the data varies from state to state, which in turn affects the usability of the data. The National Highway Traffic Safety Administration

(NHTSA) administers grant funds to help states improve their safety data systems. A review of crash data systems for nine states showed that some states enter the crash information within a week and some states take a year or more. Some systems were better than others, but overall the crash data systems in the United States have a need for improvement. NHTSA has six criteria which States must follow in developing their crash data systems. Below is the description for each criterion.

EXHIBIT V-19**NHTSA Recommended Criteria for Assessing Quality of Crash Information**

Criteria	Significance
<i>Timeliness</i>	
Crash information should be available for analytical purposes within a useful time frame for identifying crash problems within a State—preferably within 90 days of crash.	Timely crash data allows for the use of up-to-date information to identify safety problems, for policy making, and for resource allocation, among other uses.
<i>Consistency</i>	
Crash information should be consistent among reporting jurisdictions within a state. It should also be consistent with the nationally accepted and published guidelines and standards, such as the Model Minimum Uniform Crash Criteria.	Uniform data within a state should allow for the timely merging of data sets and the identification of traffic safety problems as they arise. In addition, states benefit by being able to compare their results nationally and with one another to identify traffic safety problems and manage and monitor progress toward fixing them. Finally, consistent state standards for determining which crashes to report allow for national comparisons.
<i>Completeness</i>	
Data should be collected for all reportable crashes in the state and on all appropriate crash variables.	Adherence to state reporting requirements permits evaluation of the effectiveness of countermeasures initiated by the state. Complete data also generate a picture of safety performance useful for states to qualify for highway safety incentive funding.
<i>Accuracy</i>	
Quality control methods should be employed to ensure accurate and reliable crash information for both individual crashes and aggregate crash information.	Comprehensive information is necessary to understand what makes a difference and has a direct impact on reducing deaths, injuries, injury severity, and costs.
<i>Accessibility</i>	
Crash information should be readily and easily accessible to the principal users of such data. This applies both to direct access of crash information from the appropriate crash databases and to standard reports generated from crash data.	Accessible data enables the data user to identify safety problems and allocate resources, evaluate recent traffic safety initiatives, fulfill reporting requirements, and respond to inquiries and requests from state legislative and executive branches, among others.

EXHIBIT V-19 (Continued)

NHTSA Recommended Criteria for Assessing Quality of Crash Information

Criteria	Significance
<i>Data Integration</i>	
Crash information should be capable of linking to other information sources. Such linking could be accomplished through the use of common identifiers or probabilistic data-matching methods.	Links make it possible to evaluate the relationship between specific roadway, crash, vehicle, and human factors at the time of a crash. They also permit these factors to be linked to health outcome data to determine the association with specific medical and financial consequences, which facilitates choosing safety priorities that have the most impact on reducing death and disability.

Source: GAO analysis based on NHTSA's Traffic Records Highway Safety Program Advisory

Apart from the state-maintained crash data systems, there are federally maintained crash databases like FARS.

For the proper evaluation of any of the strategies described, before and after accident study is required to evaluate effectiveness. In the evaluation of the treatment the process measure would be the number of head-on crashes reduced, along with any change in total crashes where the treatment is applied. The crash data system should be updated regularly to include the changes, if any, done to the roadway.

Many data systems do not have the capability to link to other data systems. Hospital data, insurance data, driver information systems, and roadway characteristics are examples of databases that could be linked to facilitate information sharing.

Provide a Link to Other Safety Initiatives

Many of the strategies in other volumes of the *NCHRP Report 500* guides are also effective in addressing head-on crashes on Interstates, even though some of them refer to non-freeway facilities. Statistics show that alcohol, drowsiness/distraction, and geometric elements such as horizontal curves are some of the contributing factors in head-on crashes. Therefore the strategies for improving safety for head-on crashes should also potentially consider such factors. The following implementation guides to address these crashes have already been developed and may be referred to:

- Run-Off-Road Collisions (Volume 6)
- Head-On Collisions (Volume 4)
- Collisions on Horizontal Curves (Volume 7)
- Aggressive Driving (Volume 1)
- Alcohol-Related Collisions (Volume 16)
- Drowsy and Distracted Drivers (Volume 14)

- Work Zone Collisions (Volume 17)
- Speed (Not completed) (TBA)
- Safety Data and Analysis (Volume 21)

Many of the strategies may be discussed in multiple guides but are present for a complete coverage of the topic. For example, if particular issues that pertain specifically to head-on crashes are not covered in the other guides, these details are covered within the text of this guide. In this way, duplication is minimized, while complete coverage of the topic is still provided.

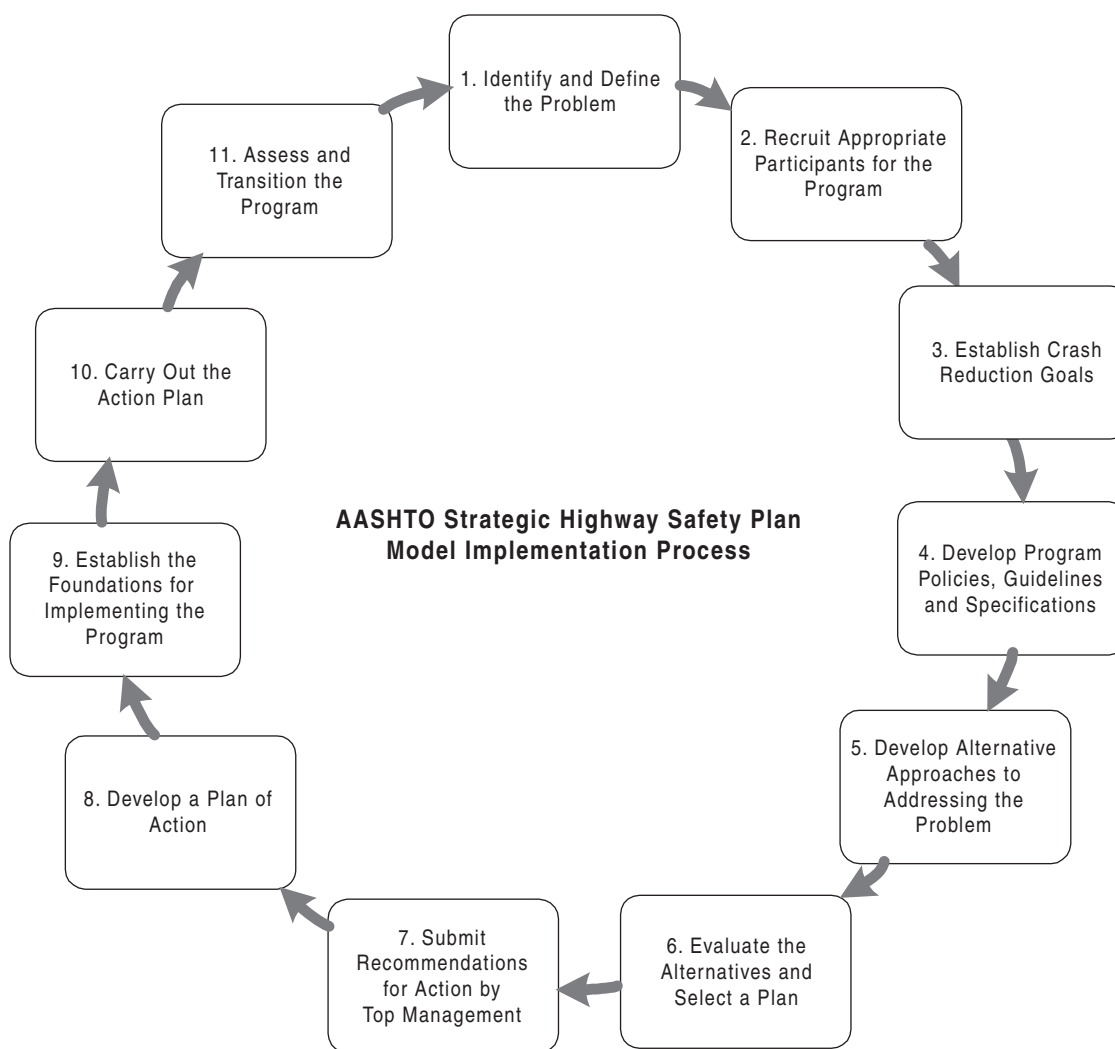
SECTION VI

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/reports/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 (*approvals 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 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 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/chhs/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://www.tc.gc.ca/finance/bca/en/Printable_e.htm.

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 are 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

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Appendixes

The following appendixes are not published in this report. However, they are available online at <http://safety.transportation.org>.

- 1 AASHTO RDG Revisions
 - 2 Arkansas DOT, Log of Cable Impacts
 - 3 Comparison of Cable Barrier Systems
 - 4 State DOT Case Studies
 - 5 Wrong Way Entry Checklist Example
 - 6 Oregon Highway Safety Corridor Program
-
- 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 Choosing the Roadway Related Strategy
 - 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 [Not Used]
 - O Estimating the Effectiveness of a Program during the Planning Stages
 - P Key Activities for Evaluating Alternative Program
 - Q Definitions of Cost-Benefit and Cost-Effectiveness
 - R FHWA Policy on Life Cycle Costing
 - S Comparisons of Benefit-Cost and Cost-Effectiveness Analysis
 - T Issues in Cost-Benefit and Cost-Effectiveness Analyses
 - U Transport Canada Recommended Structure for a Benefit-Cost Analysis Report
 - V Overall Summary of Benefit-Cost Analysis Guide from Transport Canada
 - W Program Evaluation—Its Purpose and Nature
 - X Traffic Safety Plan for a Small Department
 - Y Sample District-Level Crash Statistical Summary
 - Z Sample Intersection Crash Summaries
 - AA Sample Intersection Collision Diagram
 - BB Example Application of the Unsignalized Intersection Guide
 - CC Joint Crash Reduction Programme: Outcome Monitoring

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation